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CARTOGRAPHIC REPRESENTATION OF GEOLOGICAL FORMATIONS.

As CARTOGRAPHIC units, in the representation of geological structure, the lithologic individual, the faunal stage and the geological formation are commonly regarded as practically identical. In reality, they are fundamentally distinct from one another. Moreover, these are not the only units which it is possible and practicable to map and bring out clearly the geological structure of the area investigated.

In the recent discussions on the units of geological mapping, one of the most important fundamental factors appears to be entirely overlooked. The two leading phases of the subject are admirably summed up in the recent articles of Messrs. Willis[1] and Cross.[2] Although, at first glance, these authors seem to present radically different views, they are not, actually, so far apart in their contentions as they would have us believe. Mr. Cross' conception is the more philosophical of the two; it is based on genetic grounds; and it is the one which must finally prevail, though the local criteria of discrimination may be diverse in different cases. In actual practice, Mr. Willis' expressed idea has the greater force and must be the one which must necessarily long be followed. But the two conceptions are not incompatible. In the practical application of the principles, the final results become very nearly identical.

To every one who has given the subject critical attention, it

[1] JOUR. GEOL., Vol. IX, p. 557, 1901. [2] *Ibid.*, Vol. X, p. 223, 1902.

must be quite evident that no standard yet proposed for the delimitation of geological units in cartographic representation exactly expresses the essential features of a complete and rational scheme. As in all classifications of natural objects, that of geological units, formations, or terranes should be in its highest type genetic in character. Moreover, it should be strictly stratigraphic, depositional or sequential, using these terms in their broadest sense to include all rock-masses, igneous, metamorphic and sedimentary. With this understanding of the theme, the most obvious characteristic of a stratigraphic scheme is not the terranes or rock-masses themselves, nor any of their contents, but their geometric elements, their bounding or stratigraphic planes. In order not to carry with it the usual narrow idea, some such term as depositional or sequential planes should be used in place of the name stratigraphic, and these titles will be hereafter given preference. The sequential, depositional or sedimentation planes have different taxonomic values according to the general scheme of classification adopted[1].

A cross-section of the cartographic units, or geological formations, as they occur in nature, may be represented by the following sketch:

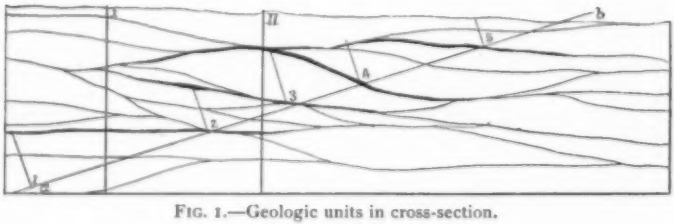


FIG. 1.—Geologic units in cross-section.

In the general, abstract or ideal instance, each lens-shaped figure is the unit established "with regard to all the facts and conditions of the case, and not upon the restricted basis of any part of those facts. It represents as much of the geological development of the earth recorded in the area covered as is practicable." The net-work of formations coincides with the

[1] *American Geologist*, Vol. XXIV, p. 294, 1899.

lines and planes of sedimentation, or natural sequence, to use a more comprehensive term. It gives a foundation for determining geologic structures and deciphering geologic events. This foundation is the same as that governing sedimentation and the sequential arrangement of rock-masses. The scheme is, therefore, genetic. It is of secondary importance to consider the composition and contents of the various lens-shaped figures. In some cases most value must be placed upon the lithologic character of a terrane. In other instances, the contained fossils, or minerals, are the determining factors. Under certain conditions still different features must be taken into consideration. The cardinal fact to be always recognized is that the cartographic unit, the geologic formation, is essentially an abstract conception. It may also be a lithologic, or faunal, or mineralogic, or physiographic, or some other kind of unit capable of being represented on maps.

As a matter of fact the lithologic features, the faunal characters, the mineralogic contents, as well as many other criteria of discrimination, are so grouped genetically to the depositional units which it is desired to represent on the map, that if the decipherable record of each were perfect, a cartographic representation of the one set of facts would in a general way indicate the probable outline of each of the other sets. But the fact that the records of all of these groups of data for the determination of the geologic formations are at best comparatively so meager, makes it incumbent upon the geologist to delimit his cartographic units at first according to the most obvious features presented in the several areas covered.

It so happens that in the field the most obvious and most useful single feature in recognizing and tracing a geological formation is the lithologic. Checked by other criteria, then, the lithologic unit corresponds very closely to the ideal cartographic unit established. For all practical purposes for which the geologic map is constructed lithologic individuals are amply sufficient and accurate. When more refined investigation is taken up some slight changes in the lines of formational delimitation may be necessary; but if the lithologic determinations

have been made with ordinary care it will probably be rare that radical alteration will be demanded.

In the present stage of geologic inquiry it is neither practicable nor desirable to map all districts with uniform refinement. Among geological formations, we shall no doubt eventually establish and indicate on all geological maps about five degrees of taxonomic rank. The division lines in any one area can only be fixed after very careful comparisons with those of all the neighboring districts. In the main, these terranal lines will be found to correspond to, or can easily be adjusted to, the divisional lines separating the lithologic individuals ordinarily recognized.

When the lithologic features of formations gradually merge into those of others, or when there is a rapid alternation of different kinds of rock layers, fossils or minerals, other criteria may have to be resorted to in order to properly delimit the terranes. But this fact certainly in no way invalidates the general principles involved in the recognition of the lithologic individual as the leading object to be represented in cartography.

When, for example, it was found upon detailed faunal examination[1] that the great St. Clair limestone of Arkansas, which had long been considered by the workers of that state as a single lithologic unit, was in reality two great limestones of almost identical lithologic appearance, the one Ordovician in age, and the other Silurian, it did not render worthless the maps upon which these two terranes had been represented as a single cartographic unit. Nor is the principle of mapping the lithologic individual to be given up on this account. Early observation was merely insufficient.

In the case of the ferruginous sandstone of southeastern Missouri and southwestern Illinois there is not a single continuous stratum, but a large number of disconnected deposits, lithologically indistinguishable, and lying, at least, at two very different geologic horizons. One horizon is below the Kaskaskia limestone and the other above that great rock-mass. The one is early Carboniferous; the other mid-Carboniferous. The lower continuous terrane is known as the Aux Vases sandstone; the

[1] *Am. Jour. Sci.* (3), Vol. XLVIII, p. 327, 1894.

other is formed by the basal sandstones of the Coal-measures. Farther southward, in Arkansas, the difference in the stratigraphic horizons of the two is upwards of 20,000 feet. Yet, because of peculiarities of position, the existence of an intervening unconformity plane, and the nearly same level above the sea of neighboring outcrops, of the two horizons on the Mississippi river, Worthen[1] and others were led to erroneously ascribe to the Kaskaskia (Lower Carboniferous) an extensive flora of the Coal-measures.

A different example is that of the Carboniferous of Arkansas. There is the enormous thickness of 26,000 feet of sediments. Sedimentation has been uninterrupted throughout the entire sequence. In the last formed terrane of the Lower Carboniferous, there begins an alternation of sandstones and shales, with some coal seams, continuing to the top of the section. About 24,000 feet of this section may be regarded as a lithological individual quite "uniformly varied in character." Data obtained farther north in Missouri show that 23,000 feet of this enormous section are unrepresented. The Arkansas section belongs to at least three great terranes, each having a taxonomic rank of series. Measured in feet, the median one alone is five times as great as all the rest of the Carboniferous represented in the Continental Interior. The conditions presented are represented below. Viewed from Arkansas alone the lines separating the distinct geological formations might forever remain unnoticed in the great lithologic individual. It is only by a comparison with sections in other localities that the terranal divisional lines may be properly drawn.

FIG. 2.—Carboniferous Sedimentation in Mississippi Valley.

There seems to be only one answer to the question: "What should a geological map represent?" That is Mr. Cross' observation that "it should represent as much of the geologic development of the earth recorded in the area covered as is practicable."

[1] *Illinois Geol. Surv.*, Vol. I, p. 79, 1866.

In considering every unit that is a possible basis for cartographic representation, a number of conditions have to be fully satisfied, in order that the best results may be obtained. As nearly as possible the unit adopted should be an abstract one, since schemes which have been elaborated, or may be in the future proposed, may not have different factors or different kind of factors to appose when the new facts are compared. The unit should be practically adaptable in order that knowledge once acquired may not have to be worked over anew in the field with each change of ideas necessitated by the constantly increasing use of more and more refined methods. The unit should be elastic, because too great rigidity of plan often breaks down the best of schemes. The unit should be easily recognizable and rapidly delimitable in the field; it should be of such character as to be readily traced from point to point, quickly run in on the map, and easily followed on the ground by subsequent investigators who may use the map.

It has been asserted that the lithologic map is a return to the so-called geological map of a century ago. It does not appear that the facts of the case warrant this statement. The geological map of today based strictly upon lithologic individuals is very nearly as fundamentally distinct from the mineralogical map of a hundred years ago, as is the modern map in which so-called geological formations are depicted. In mapping the geological features of an extensive region, work such as the federal government and some of the state geological surveys are engaged upon, the lithological individual for cartographic representation necessarily takes precedence over all other features. It will be a long time after the geological map based upon lithology principally is ready to be issued, that the perfected map of ideal geological formations can be made. In the majority of cases the delimitation of the latter must always rest very largely on the lithologic characters. A map of units recognizable in the field only after about as much study as was devoted to the terranes in the first place by the expert stratigrapher is of small practical use.

For a long time yet in modern areal work, the lithologic indi-

vidual, delimited if necessary by the aid of other criteria, appears amply comprehensive and exact for all purposes to which the ordinary geological map is put. As an aid in the development of the mineral resources of the country—the primary object of work of this kind—maps in which the lithologic individual is the unit amply suffice. In practice in the field, the units broadly defined by the lithologic characters, and those indicated by the more philosophical geologic formations, are generally near enough alike to enable future investigators to do their work without hindrance or uncertainty.

The suggestion of a faunal map eventually following the lithologic map as an integral part of a complete geologic atlas appears somewhat infelicitous. There is certainly no room whatever for such a dual plan in mapping. Such a scheme merely leads to others, maps based upon every criterion known or which may be devised. This is a proposition for which there is not the slightest demand. It is beyond all probability that parallel subdivisions should ever be found that are based upon radically different criteria. When we consider a dual scheme with a structural phase and a time phase based entirely upon fossils we are considering incongruous things. And there is not necessarily any logical connection.

In Europe, there is a classification generally presented that is dual in character, though with singular nomenclature. Thus, all the subdivisions of terranes and of time are strictly paralleled. The International Geological Congresses have adopted the same plan. It must be quite evident to the practical field geologist that there are very serious objections to this scheme. The critical criteria in the rock-scheme and in the time-scheme are fundamentally distinct. In fact, they have no genetic relationships whatever.

In reality, we have more than a dual scheme of classification in geology. There is a triple scheme, a quadruple scheme, and schemes multiple according to the number of standards involved. Each standard gives rise to a different scheme.

The principle underlying the classification of natural phenomena is that different kinds of criteria give rise to different

taxonomic groups. The arrangement of rock-masses affords no exception to the rule. If the life phases be used as the predominant feature in delimiting the subdivisions of one order, prevailing lithologic character may be given greatest weight in another; physiography or specific biotic aspect in a third. Matters are greatly simplified by regarding the larger subdivisions of the geologic scale as essentially arbitrary, abstract time divisions, in which lithology has no place. With the smaller subdivisions, which are best considered as essentially structural divisions, the time element may be practically neglected.

While we have to allude to the time-interval, during which every rock-mass was formed, we have only universal structural units represented in the major two of the five taxonomic categories usually recognized. On the map, the expression of the time of formation of the terrane is by a distinctive color. The smaller of the universal time-units is thus represented. In like manner, only one of the rock categories becomes important on the map, and this is commonly represented by a standard pattern. This, too, is the smallest unit that is of broad geologic significance. While this plan does not always meet every case, it only needs slight adjustment from time to time in order to make it the most serviceable, the most practical, the most elastic, and most nearly in accord with local facts, of any scheme yet devised.

After all, the cartographic unit, like the species in zoology or botany, is necessarily a matter of convenience. In the exact delimitation of both, there enters very largely an element of personal judgment. Through the consensus of opinion we finally arrive at a tolerably good idea of what each unit should be.

It is commonly recognized that the principal criteria followed in delimiting the several taxonomic orders of units and in geological classification are (1) the relative progress of life in general as compared with that now existing; (2) the prevailing biotic type; (3) the general lithologic phase; (4) the specific lithologic character; and (5) the specific fossil feature.

Reference is here made to our most approved ideal classification because the lithologic individual fits closely into this scheme as the taxonomic subdivision of the fourth order. The

case of the St. Clair limestones of Arkansas, already referred to, and the formations of the Rico mountains, mentioned by Mr. Cross, are good examples in which strict lithologic separation was not obvious at first glance. In reality, Cross and Spencer's "Hermosa," "Rico," and "Dolores" formations approach definite geological formations only approximately. They represent no nearer the real geological formation than do purely lithologic individuals. Exact faunal studies in the Rico and neighboring districts are likely to require the divisional lines to be drawn at quite different horizons. When the fuller geological history of the region shall have been made out further rectification will doubtless be found necessary.

As a matter of fact, the lithologic individual based primarily upon lithology and secondarily upon fossils contained, and the "geological division" based upon the fossil characters have essentially the same kind of values as geological elements. But Mr. Cross, in his delimitations, does not depend entirely upon the faunal features, for he goes on to reënforce his statements by giving other reasons for drawing his lines where he does. Lithologic features are manifestly among the most important criteria in tracing the "formations." In the same way it is quite apparent that the advocates of strictly lithologic individuals in mapping do not and cannot depend wholly upon a uniform rock character.

This phase of the question leads to the statement of a more general one, that the main thing is to give clearer definition, than has usually been done, of each cartographic unit proposed. The unit should be defined according to (1) geographic distribution, (2) topographic expression, (3) lithologic nature, (4) stratigraphic delimitation, (5) biotic definition, and (6) mineral content.

When this shall have been done the foundation will have been laid for the establishment of real Geological Formations expressive of the geological history of the area mapped. The approximate "lithologic" map will not have to be materially changed, but only accompanied by a few words of additional explanation.

CHARLES R. KEYES.

THE MISNAMED INDIANA ANTICLINE.[1]

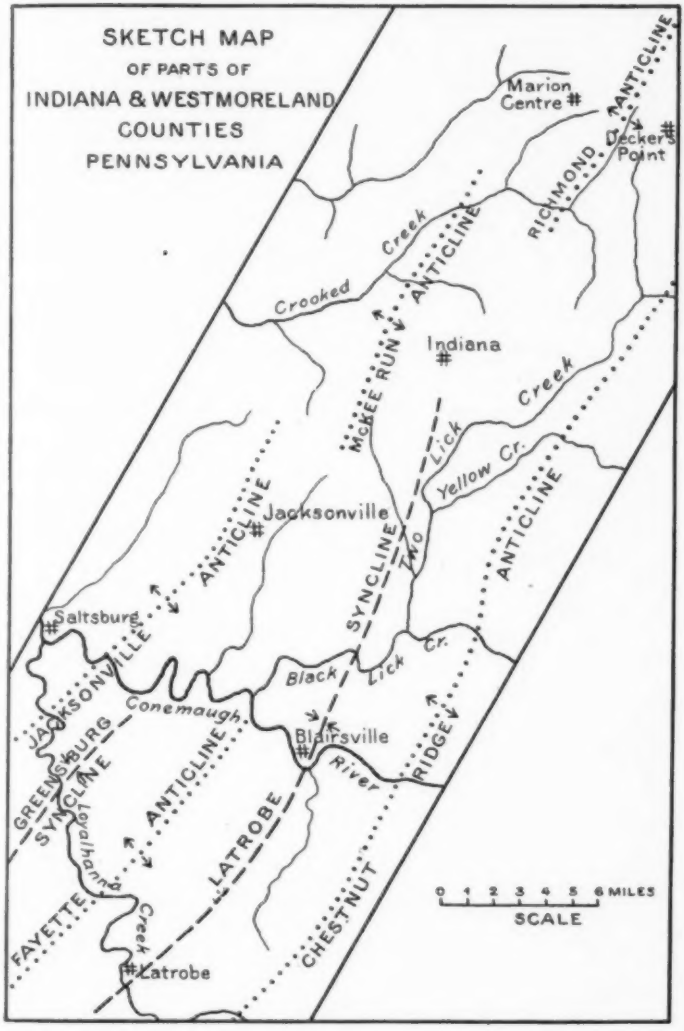
RECENT work by the United States geological survey in western Pennsylvania has revealed a number of unsuspected facts of geologic structure. The results are being published in folios in which the lay of the rocks is shown by deformation contours, but it is thought desirable to call attention here to the finding of a syncline where formerly there was considered to be an anticline.

The map of Indiana county issued by the second geological survey of Pennsylvania shows the Indiana anticline to extend in a straight line through the town of Indiana. This supposed fold has been thought to be continuous on the southwest with the Fayette anticline in Westmoreland county and on the northeast with the anticline which is well marked near Richmond, on Little Mahoning Creek. The name Indiana anticline, therefore, has been applied to the entire fold. This term has passed into geologic literature and is still being used.

In the area adjacent to the type locality of the fold, however, the structure, as indicated by the accompanying sketch map, is quite different than previously interpreted. The Richmond and Fayette anticlines are not continuous, but the former pitches southwestward and the latter pitches northeastward, and the area between the Conemaugh River and Crooked Creek, along the extension of the axes of these folds is occupied by the Latrobe syncline. It is an odd coincidence that the axes of the Richmond and Fayette anticlines fall in line with each other, and it is not surprising that these folds have been thought to be continuous, for in the intervening region surface exposures are poor and the structure can be deciphered only by detailed work. The present determination is fully proved by the records of some fifty diamond drill holes lately put down by the Rochester and Pittsburg Coal and Iron Company.

Structural details will be published in the forthcoming Indiana

[1] Published by permission of the director of the United States geological survey.


SKETCH MAP
OF PARTS OF
INDIANA & WESTMORELAND
COUNTIES
PENNSYLVANIA
Marion Centre
Decker's Point
RICHMOND ANTICLINE
Crooked Creek
ANTICLINE
McKEE RUN
Indiana
Lick Creek
Yellow Cr.
Two
ANTICLINE
Jacksonville
SYNCLINE
ANTICLINE
Saltsburg
JACKSONVILLE
Black Lick Cr.
Conemaugh
Blairsville
River
RIDGE
GREENSBURG SYNCLINE
ANTICLINE
LATROBE
Loyalhanna Creek
FAYETTE
CHESTNUT
Latrobe
0 1 2 3 4 5 6 MILES
SCALE

and Latrobe folios, so that only a few words need be added in explanation of the map. West of the Chestnut Ridge anticline the Latrobe syncline forms the northern extension of the Connellsville basin. This syncline rises and flattens out between Blairsville and Indiana, displacing the two westward succeeding folds. These folds are the Fayette anticline and the Greensburg syncline. Well developed where they cross Loyal Hanna Creek, northward in the vicinity of the Conemaugh River they fade away and merge into the western flank of the Latrobe syncline. The next fold to the west is the Jacksonville anticline, which has its maximum development near the town of Jacksonville. Southwest of Indiana there is an offset in the axis of this fold. Thence the arch continues northeastward, as the McKee Run anticline, and forms a low fold separated from the Chestnut Ridge anticline by the extension of the Latrobe syncline. Northeast of Indiana this syncline is divided in two by a south-plunging anticline, which, passing between Decker's Point and Marion Center, is well marked near the town of Richmond.

GEORGE B. RICHARDSON.

WASHINGTON, D. C.

REVISED CLASSIFICATION OF THE UPPER PALEOZOIC FORMATIONS OF KANSAS.

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Chase stage.

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Florence flint.
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INTRODUCTION.

IN 1895 the writer published a paper on "The Classification of the Upper Paleozoic Rocks of Central Kansas" in the JOURNAL OF GEOLOGY.[1] Additional field work and study of the Cottonwood Falls quadrangle render it advisable, in compliance with the custom of the United States Geological Survey to designate each lithologic individual capable of representation on the topographic map as a formation, to subdivide three of the units which were described as formations in that article.

A few changes in classification or nomenclature have been made which are also explained in this paper. Dr. J. W. Beede,

[1] Vol. III, pp. 682–706, and pp. 764–801.

of Indiana University, who has been associated with the writer in this later study, has rendered most efficient service in the field and other work necessary for this revision. Dr. George I. Adams, of the United States Geological Survey, spent several days with Dr. Beede in examining part of the area of the Cottonwood Falls quadrangle, and Mr. F. B. Weeks has also kindly furnished the author with references to the descriptions of formations from the United States Survey card catalogue of geologic formation names.

CLASSIFICATION.

WABAUNSEE STAGE.[1]

None but the upper rocks of this stage are exposed on the Cottonwood Falls quadrangle and the lower ones, exposed to the eastward, have not been carefully examined by the writer.

Burlingame limestone.—At the base of the Wabaunsee is a conspicuous and persistent limestone from seven to twelve feet in thickness, the lower limit of which is regarded as the lower line of that stage. It was named and briefly described by Hall in 1896[2] from outcrops near Burlingame and since then it has been traced from Nebraska across the state to Oklahoma.[3]

This limestone is frequently composed of two layers, gray to brown in color, separated by shale, and forms a massive ledge. This is apparently the division which was termed "limestone number 9" by Professors Haworth and Kirk, in 1894, exposed near the junction of the Cottonwood and Neosho rivers, which they stated "may be called the *Wyckoff limestone* . . . . on account of its great exposure in the vicinity of Wyckoff.[4]" This name, however, ought to be considered a synonym, for Dr. Sardeson had already given an almost identical one to a division of

[1] The word stage is used in the sense adopted by the International Congress of Geologists. See *Work Inter. Cong. Geologists*, 1886, p. 50; GILBERT, in *Proc. A. A. A. S.*, Vol. XXXVI, 1888, p. 186; Congrés Géologique International (8e Session), *Procès-verbaux des Séances*, 1901, p. 35; and *ibid., Comptes Rendus*, 1er Fasc., 1901. p. 196.

[2] *Univ. Geol. Surv. Kansas*, Vol. I, p. 105.

[3] See, "Map of Limestone Outcroppings," by PROFESSOR HAWORTH, Vol. III, *Univ. Geol. Surv. Kan.*, 1898, Pl. VII.

[4] *Kan. Univ. Quart.*, Vol. II, Jan. 1894, p. 111.

Carboniferous system (upper

CLASSIFICATION OF THE UPPER PALEOZOIC FORMATION

- **Permian system. (?)**
  - **Cimarron series**[2] - Cragin, '96.
    - Kiger Stage[2] - Cragin, '96.
      - Taloga formation
      - Day Creek dolomite
      - Red Bluff formation
    - Salt Fork Stage - Cragin, '96.
      - Dog Creek formation, Crag
      - Cave Creek formation, Crag
      - Glass Mountain formation, Crag
      - Kingfisher formation, Crag
  - **Big Blue series**[3] - Cragin, '96.
    - Summer Stage - Cragin, '96.
      - Wellington shales[7]
      - Marion formation
    - Chase Stage - - - Prosser, '95.
      - Winfield formation
      - Doyle shales
      - Fort Riley limestone
      - Florence flint
      - Matfield shales
      - Wreford limestone
- **Carboniferous system (upper part only). (?)**
  - **Missourian Series**[4] - Keyes, '96. (Upper part of series)
    - Council Grove Stage.
      - Garrison formation,
      - Prosser and
      - Alma limestone
    - Wabaunsee Stage - Prosser, '95.
      - Eskridge shales
      - Neva limestone
      - Elmdale formation
      - Americus limestone
      - ——— formation
      - Emporia limestone
      - ——— shales
      - Burlingame limestone

[2] The classification of the formations from the top of the Kiger to the Wellington shales, inclusive, is that of Dr. Cragin, except that he termed Kiger and Salt Fork *divisions* of the Cimarron series (*Col. Coll. Studies*, Vol. VI, March 27, 1896, pp. 3, 16–49). The following year Dr. Cragin revised the classification of the Cimarron series, changing the limits and names of some of the formations and drawing the line of separation between the Salt Fork and Kiger divisions at the *top* of the Dog Creek formation instead of at its *base*, as in the former classification (*Am. Geol.*, Vol. XIX, May, 1897, pp. 351–64).

[3] *Col. Coll. Studies*, Vol. VI, pp. 3, 18, 48; and see additional account in *Am. Geol.* Vol. XIX, May, 1897, pp. 351–64.

[3] *Col. Coll. Studies*, Vol. VI, March 27, 1896, pp. 3, 5, 6. In July, 1896, Dr. Keyes proposed "to recognize in the 'upper' Carboniferous of the Western Interior province three series having equal taxonomic rank," the upper one of which was named the "Oklahoman" (*Am Geol.*, Vol. XVIII, p. 25). In defining the series it was stated that "In suggesting the name 'Oklahoman' as a serial geological term it is intended to apply to all those rocks of Carboniferous age which occur north of the Canadian river in Oklahoma, and which lie between the interval of the top of the Missourian series and the base of the Cretaceous. It may be regarded as essentially covering the same succession of strata that has long been vaguely known under the title of 'Permian.' The name is derived from the territory in which the formation has its best development and in which the most complete sequence is represented" (*ibid.*, p. 27). In October, 1891, Dr. Keyes recognized the Cimarron series and gave the Oklahoman and Cimarron as the two closing series of the Carboniferous (*Am. Jour. Sci.*, 4th ser., Vol. XII, pp. 306, 309), stating that "The so-called Permian of the Western Interior basin (Oklahoman and Cimarron, the latter generally known as the Red Beds) is composed largely of shales and shaly sandstones. . . . . The conditions existing were identical with those under which the original Permian beds of Russia were formed" (*ibid.*, p. 309). The following month Dr. Keyes published a "General Geological Section of the Carboniferous of the Mississippi Valley," in which a complete list of the series and terranes of the system is given. For the portion under consideration it is as follows:

Series.	Terranes.
Carboniferous system (upper portion). — Cimarron	Kiger shales.
	Salt Fork shales.
Oklahoman	Wellington shales.
	Marion limestone.
	Chase limestone.
	Neosho shales.
Missourian (upper part)	Cottonwood limestone.
	Atchison shales.

(*Am. Geol.* Vol. XXVIII, p. 302.) I
defined above is identical with the B
therefore his name, which has priority,
only change from Professor Cragin's c
member at its base is put in the Misso
in 1902 (*Twenty-first Ann. Rept. U*
apparently the same as the Cimarron s

[4] "Missouran" was proposed a
(*Am. Geol.*, Vol. XVIII. pp. 25-27).
mation which was proposed by him
Mon. Rev. Iowa Weather Service,

[5] Nearly three years later Profe
stone" to a formation occurring in no
1900, Vol. IX. pp. 203, 205, which was
165, 1900, p. 78).

[6] It is not probable that "Harp
because the very similar term of "Ha
as the name of a formation occurring
Harpers Ferry folio (Folio 10), 189

[7] The term "Wellington shales,"
an article by Professor Cragin, in the
VIII, April, 1895, p. 679; and a little
Laboratory of Natural History, V

rmation-	Cragin, '97.
k dolomite	Cragin, '96.
formation	Cragin, '96.
k formation, Cragin, '96.	Chapman dolomite,[5] Cragin, '97. Amphitheatre dolomite, Cragin, '97.
k formation, Cragin, '96.	Shimer gypsum - Cragin, '96. Jenkins clay - Cragin, '96. Medicine Lodge gypsum, Cragin, '96.
ntain formation, Cragin, '97.	Flower-pot shales - Cragin, '96. Cedar Hills sandstone, Cragin, '96.
formation, Cragin, '97.	Salt Plain member - Cragin, '96. Harper sandstone[6] - Cragin, '96.
n shales[7]	Cragin, '96.
rmation	Prosser, '95.
ormation	Prosser, '97.
les	Prosser and Beede.
limestone	Swallow, '66.
lint	Prosser, '95.
hales	Prosser and Beede.
imestone	Hay, '93.
ormation, Prosser and Beede.	Neosho member - Prosser, '95. Florena shales, Prosser and Beede.
stone	Prosser, '94.
shales	Prosser and Beede.
stone	Prosser and Beede.
ormation	Prosser and Beede.
limestone	Kirk, '96.
rmation	
imestone	Kirk, '96.
ales	
e limestone	Hall, '96.

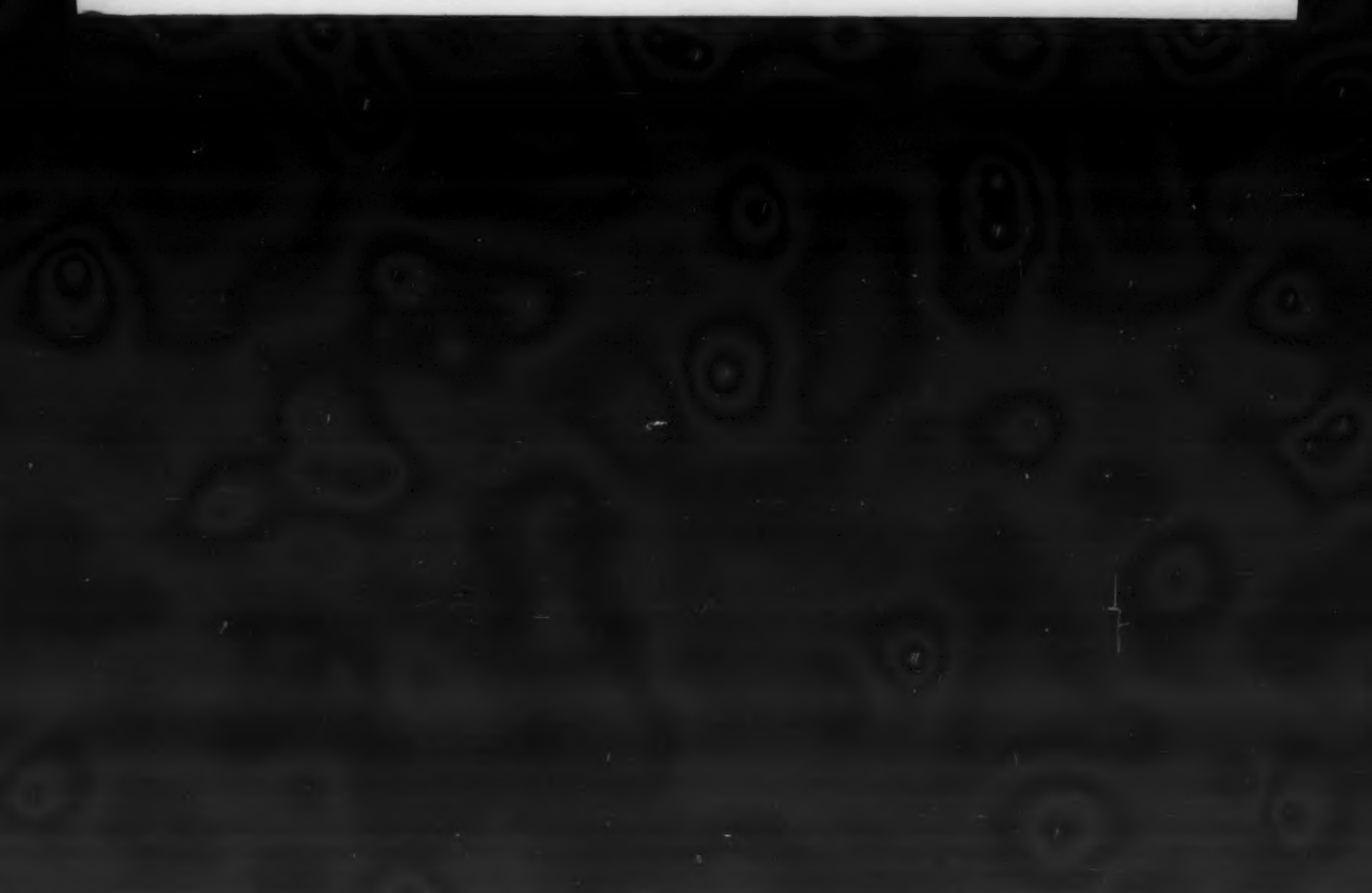
XXVIII, p. 302.) It will be seen that the Oklahoman series, as precisely identical with the Big Blue series proposed by Dr. Cragin in 1896, and e, which has priority, is adopted for this classification. In my revision the Professor Cragin's classification of the Big Blue series is that the Neosho e is put in the Missourian series. The Brazos series proposed by Prof. Hill *first Ann. Rept. U. S. Geol. Surv.*, Pt. VII, p. 100) for the Red Beds is me as the Cimarron series of Cragin.

an" was proposed as the name of a series by Dr. Keyes, in July, 1896 XVIII, pp. 95-97). This was an outgrowth of the Missouri stage or forn proposed by him in 1893 (*Iowa Geol. Surv.*, Vol. I, pp. 85, 114; and *Weather Service*, Vol. IV, p. 3).

ee years later Professor H. S. Williams gave the name "Chapman sandnation occurring in northeastern Maine (*Am. Jour. Sci.*, 4th ser., March, 203, 205, which was more fully described in *Bull. U. S. Geol. Surv.*, No.

robable that "Harper sandstone" can be retained for this subformation, similar term of "Harper's shale" was published by Keith two years earlier formation occurring near Harper's Ferry (*Geologic Atlas United States, folio* (Folio 10), 1894, pp. 3, 5).

"Wellington shales," apparently applied to this formation, first appeared in fessor Cragin, in the Kansas City *Review of Science and Industry*, Vol. p. 679; and a little later he published it in the *Bull. Washburn College Natural History*, Vol. I, May (?), 1885, p. 86.



the Cincinnati series of the Ordovician in Minnesota, for which he proposed "a new name . . . . *Wykoff* beds — from the town near which the best exposure known occurs."[1] and this he later called the Wykoff formation.[2] The only difference is that the name of the Minnesota town is spelled without a *c*. In 1895 Professor Haworth proposed the name "Osage City shales" for the rocks included between the top of the Topeka limestone and the base of a thin limestone overlying the Osage coal; while about 150 feet of the superjacent rocks in the vicinity of Burlingame were named the Burlingame shales.[3] Later in the same year both divisions were more fully described by Professor Haworth;[4] but the upper limit of the Burlingame shale was not precisely defined. The following year Mr. Hall applied the term "Burlingame limestone" to eight feet of limestone which "covers the third and last heavy bed of shales in this section" with a thickness of 150 or 200 feet.[5]

This shale was apparently regarded by Mr. Hall as the Burlingame, since he used that name in the list of subjects at the beginning of his chapter,[6] and then the heading following that of the Burlingame limestone is the "Systems above the Burlingame shales."[7]

In 1898 Professor Haworth stated that "subsequent work has shown the unimportance of" the thin limestone overlying the Osage coal, "so that it will not do to depend upon it as a division line marker. Neither will the Osage coal serve such a purpose, as it is by no means continuous . . . . From these considerations it seems desirable to let the name Osage apply to the entire shale bed above the Topeka limestone and below the Burlingame limestone . . . This renders the name Burlingame shales superfluous and therefore it will be dropped."[8]

[1] *Bull. Minn. Acad. Nat. Sci.*, Vol. III, No. 3, 1891 (?), p. 326. It is stated by Professor N. H. Winchell and E. O. Ulrich that this paper was not distributed until April 9, 1892 (*Geol. Minn.*, Vol. III, Pt. I, of the final report, 1895, p. XLVI).

[2] *Am. Geol.*, Vol. XIX, Jan., 1897, p. 24; see also *ibid.*, May, 1897, pp. 332, 334.

[3] *Kan. Univ. Quart.*, Vol. III, April, 1895, p. 278.

[4] *Am. Jour. Sci.*, 3d ser., Vol. L, December, 1895, pp. 461, 462.

[5] *Univ. Geol. Surv. Kan.*, Vol. I, 1896, p. 105. [6] *Ibid.*, p. 99. [7] *Ibid.*, p. 105.

[8] *Ibid.*, Vol. III, p. 105; also see p. 73.

In 1898 Dr. Adams applied the name "Eureka limestone" to a formation exposed in the vicinity of that city,[1] which Professor Haworth correlated with the Burlingame limestone.[2] The name Eureka, however, was preoccupied, since Hague used it in 1883 for the Eureka quartzite of Nevada,[3] and later Dr. Branner named the Eureka shale of Arkansas.[4]

——— *shales.*— In Lyon county, succeeding the Burlingame limestone, according to Mr. Alva J. Smith, are nearly forty-five feet of blue to yellow shales and friable limestones, the latter comprising about eight feet of the total thickness of this formation, which is limited at the top by the Emporia blue limestone.[5] Dr. Adams has recognized as a formation the shales included between the Burlingame and Emporia limestones, which he has named in manuscript, and therefore no name is proposed for the division in this article.

Emporia limestone.— This division, as described by Mr. Smith, is composed of three feet of hard blue limestone at the base, the upper six-inch layer making a good flagstone, which is extensively used in Emporia. Then there is four feet of shale capped by another hard blue limestone two feet in thickness. These limestones "pass under the Cottonwood River at Soden's mill, one mile south of Emporia,"[6] and the Neosho River at the Rinker bridge. It was named by Kirk in 1896,[7] but, according to Mr. Smith, at some of the localities which he mentioned it was confused with a higher limestone. The blue Emporia limestone was correctly reported by Kirk in the "Chicago Mound" near Wyckoff; but the limestones near the "Emporia waterworks" and "along the hilltops about four miles south and one mile east of Emporia"[8] are higher and belong in what Mr. Smith named the "Emporia system."[9] The lower limestone

[1] *Ibid.*, p. 67. [2] *Ibid.*, p. 73. [3] *Third Ann. Rept. U. S. Geol. Surv.*, pp. 253, 262.

[4] *Ann. Rept. Geol. Surv. Ark.*, for 1888, Vol. IV, 1891, p. 13, and see description by Professor Simonds on p. 26.

[5] See *A Bulletin on Lyon County Geol.*, 1902, pp. 2, 10; and *Trans. Kan. Acad. Science*, Vol. XVII, 1901, p. 193.

[6] *Bull. Lyon County Geol.*, pp. 2, 10; and *Kan. Acad. Sci.*, Vol. XVII, p. 193.

[7] *Univ. Geol. Surv. Kan.*, Vol. I, p. 80. [8] *Ibid.*, p. 82.

[9] Letter of Mr. Smith, Jan. 20, 1902. For a description of the Emporia system see *Bull. Lyon County Geol.*, p. 3.

was called the "Emporia blue" by Mr. Smith,[1] who states that it is much more uniform than the upper, and that he has traced it across Lyon county. He also identified it two miles east of Harveyville, in Wabaunsee county, and four miles northwest of Eureka, in Greenwood county. It appears to be a persistent limestone for some considerable distance, which can be traced and mapped, and is, therefore, probably entitled to rank as a substage of the Wabaunsee.

——— *formation.*— Above the Emporia limestone, as described by Mr. Smith, is a zone nearly seventy feet thick, composed mainly of shale, but with a foot of limestone and a five-inch stratum of coal in the lower part, and a five-foot sandstone near the top. Then comes a zone composed of five limestone strata from one to two feet in thickness, separated by shales from four to ten feet thick, and with a total thickness of twenty-four feet. Mr. Smith named this zone the Emporia system,[2] and has represented its distribution three-fourths of the distance across Lyon county.[3] He writes me, however, that "the five limestones which I have included in the Emporia system are not very persistent, and the character and thickness of the stone, as well as the intervening shale, are subject to sudden changes. I have been unable to identify it beyond the lines of this county."[4] It hardly appears desirable to regard this zone as entitled to the rank of a formation. Then, according to the measurements of Mr. Smith, there are 210 feet of rocks composed largely of sandy shales, but also containing some thin beds of limestone, coal, and sandstone. The most important coal stratum is ten inches in thickness, and it occurs 75 ½ feet above the base of this member. So far as I am able to judge, it would appear advisable to put these three members in one formation, giving it a thickness of about three hundred feet. Dr. Adams ranked the rocks included between the Emporia and Americus limestones as a formation, which he has named in manuscript, and, therefore, no name is proposed for this formation.

[1] *Ibid.*, p. 2. [2] *Bull. Lyon County Geol.*, 1902, p. 3.

[3] *Trans. Kan. Acad. Sci.*, Vol. XVII, 1901, p. 191; and *Bull. Lyon County Geol.*, p. 8.

[4] Letter of January 20, 1902.

Americus limestone.— This name was given by Kirk in 1896 to two thin layers of limestone, separated by shale, which are quarried near Americus.[1] It was also noted by Haworth and Kirk in their "Neosho river section" and called "limestone system No. 11."[2] The lower stratum is buff in color, very solid and compact, making a good building stone with a thickness of twenty-one inches, according to Smith. Then comes six feet of shale with a six-inch flag limestone on top,[3] making a total thickness of over eight feet, and its distribution has been mapped entirely across Lyon county by Smith.[4] On the Cottonwood Falls quadrangle it is probable that this limestone is only a few feet below water in the Cottonwood River east of Elmdale.

Elmdale formation.— This formation, the succeeding ten and the lower and middle parts of the Marion, are represented on the Cottonwood Falls quadrangle, which has also furnished the majority of the names, and consequently these have been more thoroughly studied by the writer than the preceding formations. It is about 130 feet in thickness, and composed of yellowish to bluish shales, with thin beds of grayish alternating limestone, including two or three thicker ones. About thirty feet above the base of the formation is a friable limestone with a thickness in some localities of four feet, which is composed to a large extent of the tests of *Fusulina secalica* Say. This stratum weathers readily and leaves great numbers of *Fusulina* in the soil. About thirty-five feet higher is another conspicuous yellowish limestone, the center of which weathers to a rough face, and from ten to fifteen feet below the top is a limestone stratum from three to five feet in thickness. The formation is limited at the base by the top of the Americus limestone, and at its top by the base of the massive Neva limestone. It is well exposed on the bluff east of Elmdale, from which town it is named.

[1] *Univ. Geol. Surv. Kan.*, Vol. I, pp. 80, 81.

[2] *Kan. Univ. Quart.*, Vol. II, January, 1894, p. 111.

[3] *Bull. Lyon County Geol.*, pp. 3, 10.

[4] *Trans. Kan. Acad. Sci.*, Vol. XVII, 1891, p. 191; and *Bull. Lyon County Geol.*, p. 8.

Neva limestone.— This formation consists of a massive bluish-gray limestone or of a lower and upper massive limestone, each one a little over four feet in thickness, separated by two feet of shales, with a total thickness of about ten feet. The limestone, forming frequent ledges seven feet or more in thickness, breaks off in large blocks with sharp angles and a rough, jagged surface, weathering to a color not dissimilar to that of bleached bones. It was noted by Swallow in 1866[1] and represents the upper stratum of Haworth and Kirk's "limestone system No. 12,"[2] to which "system" Kirk later apparently applied the name "Dunlap limestone."[3] The limestone is finely exposed in the anticlinal fold to the northeast of Neva, a station on the Atchison, Topeka & Santa Fe railroad near the junction of the Diamond Creek and Cottonwood River valleys, hence its name.

Eskridge shales.— Between the Neva and the next higher massive limestone is a mass of shales, with perhaps some thin limestone layers, varying from thirty to forty feet in thickness. The shales are of greenish, chocolate, and yellowish color, and usually form covered slopes between the two conspicuous limiting limestones. They form the upper division of the Wabaunsee stage, and are named from the exposures in the vicinity of Eskridge, Wabaunsee county.

COUNCIL GROVE STAGE.

In my original description of these formations the line of separation between the Upper Coal-measures and Permian was doubtfully drawn between the Cottonwood and Neosho formations;[4] while the Permian appeared as a series of the Carboniferous, in accordance with the usage of the United States Geological Survey.[5] Since then Dr. Frech has reviewed this classification and drawn the lower line of the lower Dyas (Permian) at the base of the Chase stage, while it is stated that the Neosho is a transition to the Carboniferous, and a distinct line fails.[6]

[1] *Prelim. Rept. Geol. Surv. Kan.*, p. 16, Nos. 82–4.

[2] *Kan. Univ. Quart.*, Vol. II, 1894, p. 112.

[3] *Univ. Geol. Surv. Kan.*, Vol. I, 1896, p. 81.

[4] JOUR. GEOL., Vol. III, 1895, p. 800.

[5] See *Ibid.*, p. 796, f. n. [6] *Lethaea palaeozoica*, Bd. II, 2 Lief., 1899, p. 378.

On the chart showing the partial distribution of the Carboniferous, the Chase is apparently given as corresponding to the lower part of the Arta stage, which, according to his classification, is the oldest stage of the Permian, and the Neosho is represented as about on the dividing line between the Permian and Upper Carboniferous, although perhaps it is intended to include all of it in the latter division.[2] It is stated, however, that the older Chase and Neosho strata (as compared with the Marion) beyond doubt can only correspond to the Artinsk stage (which is the oldest Permian of Russia=Arta stage), and that a sharper division is made impossible by the absence of Cephalopods.[2] It is to be noted that in the latter part of this work devoted to "Die Dyas," in the table of Kansas Dyassic formations, Dr. Frech has left the Neosho as the oldest division of the Palæo-Dyas. In this case, however, he was reporting the classification of Professor Cragin, for it is stated that in the following table the Kansas strata are enumerated according to a recent survey, and it is not thought that he intended to set aside his earlier correlation.[3]

In reference to the correlation of these divisions the writer has stated that "The appearance and the prominence of the *Pseudomonotis* fauna in the Neosho formation furnishes a strong reason on the biologic side" for its correlation with the Permian.[4] The presence of *Pseudomonotis* is no longer an important argument in favor of putting the Neosho in the Permian, because since then Dr. Beede has identified *Pseudomonotis Hawni*, and described a new variety of that species and two new species from the older formations of the Upper Coal-measures of Kansas.[5]

There is a marked lithologic change at the base of the Chase stage where it begins with the Wreford limestone, which is the lowest one of the very cherty massive limestones. It is perhaps

[1] *Ibid.*, "Tab. XXIV, Einige wichtige Vorkommen des Carbon."

[2] *Ibid.*, p. 377, f. n.: "Dass die tieferen Chase- und Neosho-Schichten nur der Artinskischen Stufe entsprechen können, steht ausser Zweifel; jedoch wird eine schärfere Abgrenzung durch das Fehlen der Cephalopoden unmöglich gemacht."

[3] *Ibid.*, 3 Lief., 1901, p. 514. [4] JOUR. GEOL., Vol. III, 1895, p. 796.

[5] *Kan. Univ. Quart.*, Vol. VIII, April, 1899, Ser. A., pp. 79–84; and *Univ. Geol. Surv.*, Vol. VI, 1900, pp. 132–35.

a more satisfactory classification to regard the base of the Permian as marked by the lower limit of the Wreford limestone and the writer is inclined to accept this line for the division as indicated by Dr. Frech. If this be done the writer would class the two formations succeeding the Eskridge shales (Cottonwood limestone and Garrison) together to form a stage for which he would propose the name of Council Grove. The upper part of the stage is well shown in the bluffs of the Neosho River and its tributaries in the immediate vicinity of this city, while the Cottonwood limestone and the overlying Florena shales may be found in the Neosho valley, about six miles below Council Grove.

Alma limestone.—This is a massive light gray to buff-colored, foraminiferal limestone, frequently composed of two layers with a thickness of about six feet. It contains very few fossils, with the exception of *Fusulina secalica* Say, which is extremely abundant in its upper part, and is called "wild rice" by the quarrymen. It is the most important dimension stone in Kansas, and at various localities are extensive quarries. Its constant lithologic character, with its line of outcrop frequently marked by a row of massive light gray rectangular blocks filled with *Fusulina*, make it one of the most important stratigraphic horizons in the Upper Paleozoic rocks for at least two-thirds of the distance across Kansas and into Nebraska. Swallow called the stratum the Fusulina limestone,[1] and for years it has been known commercially as the Cottonwood or Cottonwood Falls limestone, and at other localities as the Alma and Manhattan limestone. Haworth and Kirk, in their "Neosho River section," called it "limestone system No. 13, which is considered the equivalent of the famous Cottonwood Falls limestone;"[2] but in their description of the quarries near Cottonwood Falls, under their "Cottonwood River section," simply called it "No. 13,"[3] and did not apply to it the term Cottonwood Falls limestone. The same year Prosser proposed the name "Cottonwood formation" for the limestone and superjacent fossiliferous

[1] *Prelim. Rept. Geol. Surv. Kan.*, 1866, p. 16.

[2] *Kan. Univ. Quart.*, Vol. II, Jan. 1894, p. 112. [3] *Ibia.*, p. 113.

shales, on account of the excellent outcrops of both in the bluffs bordering the Cottonwood River below and above Cottonwood Falls and Strong. The lower division was named the "Cottonwood limestone" and the upper the "Cottonwood shales,"[1] while the same limestone quarried in the vicinity of Alma was mentioned locally as the "Alma massive limestone."[2] The following year the formation and its two members were more fully described by Prosser.[3] The name "Cottonwood," however, was apparently used for a geological division by N. F. Drake as early as September, 1893, when he described the "Cottonwood Creek bed" of the Texas Carboniferous.[4] It is now proposed to limit the formation to the Cottonwood limestone and on account of the prior use of the name Cottonwood for the Texan bed, to call it the Alma limestone from the outcrops near the town of that name in Wabaunsee county, while the Cottonwood shales are referred to the succeeding formation.

Garrison formation.—This formation is composed of two members, the yellowish fossiliferous shales at the base, formerly called the Cottonwood shales, and the upper one, composed of the alternating gray limestones and various colored shales called the Neosho, with a total thickness of from 140 to 145 feet. The lower shales have a thickness of thirteen feet near Strong, but decrease to two or three feet in the northern part of the state. The lower part of these shales contains immense numbers of a few species of fossils and on this account may be readily identified wherever outcrops occur. Since the geographic name "Cottonwood" is preoccupied the term "Cottonwood shale" is abandoned, and they are renamed the Florena shales from the exposures over the Alma limestone in the quarries near Floren, in the Big Blue valley.

The upper member of the formation is composed of green, chocolate, and yellowish shales alternating with grayish limestones, while in the Big Blue valley a bed of gypsum occurs near the base. Certain layers of the coarser shales and limestones

[1] *Bull. Geol. Soc. Amer.*, Vol. VI, Nov. 1894, p. 40.

[2] *Ibid.*, p. 44.

[3] JOUR. GEOL., Vol. III, Oct. 1895, pp. 697–705.

[4] *Fourth Ann. Rept. Geol. Surv. Texas*, pp. 374, 382.

contain an abundant Lamellibranch fauna, and the entire fauna is thought to be a mixture of species found in the western Coal-measures, together with others occurring in the division generally termed the Permian or the Permo-Carboniferous. This member was originally termed the Neosho formation from the excellent outcrops in the Neosho valley near Council Grove.[1] The Florena shales and Neosho member are now united to form the Garrison formation, so named on account of the good exposures from Garrison south in the Big Blue valley.

CHASE STAGE.

As in the case of the Wabaunsee, it has been found advisable for mapping to divide this stage, which was formerly called the Chase formation, into several formations, which are described in ascending order. These subdivisions of the Wabaunsee and Chase stages are sufficiently definite lithologic divisions to be traced across the Cottonwood Falls quadrangle, and some distance to the north and south, and therefore can be mapped. It does not appear to the writer, however, that these divisions are entitled to the rank of a stage, and he would term them substages. If we consider the well-known Hamilton division a stage of the New York Devonian, then it would appear that these divisions correspond more nearly to the Moscow shales, Encrinal limestone, Ludlowville shales, and other subdivisions of that stage, than to the entire Hamilton.

Wreford limestone.—This formation is composed of limestone and chert, or flint as it is popularly termed throughout the Flint Hills region, and varies in thickness from thirty-five to fifty feet. In general it is composed of three strata, a cherty limestone below and above, separated by a heavy limestone nearly free from chert. The rock is buff in color, often weathering much lighter, and forms the first conspicuous flint terrace above the Alma limestone. It is quite extensively quarried and used for construction stone or crushed for railroad ballast. It was called the Strong flint in 1895,[2] but is now known to be the equivalent of the Wreford limestone, which was named by

[1] JOUR. GEOL., Vol. III, 1895, p. 764. [2] JOUR. GEOL., Vol. III, p. 773.

Professor Hay in 1893 from exposures near Wreford, Geary county, south of Junction.[1] The preceding report of the State Board contained the same table of Professor Hay's "Fort Riley section," except that this division was called the "Walford limestone," which was undoubtedly a typographical error for Wreford.[2]

Matfield shales.—The formation is composed principally of variously colored shales, with some shaly buff, occasionally cherty limestones, and a light gray limestone two feet or so in thickness, which occurs about thirty feet below its top. The thickness ranges from sixty to seventy feet, and it generally forms covered slopes between two massive and conspicuous flint ledges. It is named from Matfield township, Chase county, where it forms the side of the steep escarpment above the Wreford limestone.

Florence flint.—This formation is about twenty feet in thickness and consists of very cherty limestone separated by definite layers of chert, with a band of shaly or white cellular limestone near the center. It is excellently exposed on the McPherson branch of the Atchison, Topeka & Santa Fé Railroad, and in the Jones quarries along that railroad, from one to two miles northeast of Florence, and on this account in 1895 it was named the "Florence flint."[3]

Fort Riley limestone.—Overlying the Florence flint is a series of massive buff limestones, changing to thin bedded and shaly strata in the upper part of the formation, which have a total thickness of forty feet or more. Near the center of the formation are generally one or two massive layers, which on the weathered surface form a conspicuous ledge that may be readily followed by the eye for miles on the bluffs of the Cottonwood and Kansas rivers. Swallow in 1866 applied the term "Fort Riley limestone" to the massive ledge in the vicinity of Fort Riley, which he described as "a buff porous magnesian rock, in thick beds," with a thickness of from eight to ten feet.[4] This

[1] *Eighth Bien. Rept. Kan. State Board Agri.*, Part II, p. 104.

[2] *Seventh ibid.*, 1891, Part II, p. 94.

[3] JOUR. GEOL., Vol. III, p. 773.

[4] *Prel. Rept. Geol. Surv. Kansas*, p. 14.

name is now adopted for this formation, but its limits are extended to include the thinner bedded limestones both below and above the massive Fort Riley main ledge. The Florence limestone[1] is apparently equivalent to the Fort Riley main ledge and the name is now abandoned.

Doyle shales.—This formation is composed of variously colored shales with an occasional thin stratum of soft limestone, and has a thickness of sixty feet. About twenty feet above the base is a thin, grayish limestone which often appears on the surface, and at the top are yellowish shales containing a few fossils. These shales and the rocks of the overlying formations weather easily and form gently undulating prairies in sharp contrast with the rough topography produced by the flint and massive limestones below. The formation is shown at various places in the Doyle Creek valley to the southwest of Florence, from which locality it is named the Doyle shales.

Winfield formation.—This has a thickness of about twenty-five feet, and is composed of a cherty limestone at the base with a massive concretionary one at the top, the two separated by yellowish shales. This chert and concretionary limestone form the highest prominent chert ledge in the Kansas Permian, and make a marked stratigraphic horizon that is of great assistance in determining the areal geology of eastern central Kansas. The chert is not so uniform in occurrence as in the Wreford and Florence flints, and at some localities this horizon is represented simply by a prominent light gray limestone, nearly free from chert. The concretions in the upper limestone are quite persistent through long stretches of outcrop, although occasionally areas are found where they are small and inconspicuous or absent. As a rule, however, they are large, and the stratum may readily be traced across the country either from its exposure in bluffs or streams or from the line of loose reddish-brown concretions stretching across the prairie. The irregular worn upper surface of the concretionary limestone and the appearance of many of the concretions, as though rolled in the mud on the sea bottom, indicate a shallowing of the sea at this time, fol-

[1] JOUR. GEOL., Vol. III, 1895, p. 773, No. 15 of the Chase section.

owed by a subsidence of the sea bottom before the deposition of the succeeding even thin bedded limestones. This change of physical condition is indicated in the fauna by the nearly complete disappearance of the brachiopods and the survival of a fauna composed mainly of Permian lamellibranchs. This formation constitutes the upper division of the Chase stage, and in the preliminary description of these rocks it was called the "Marion flint and concretionary limestone"[1] from the outcrops below Marion, and regarded as a subformation. The overlying buff limestone and shales, however, were named the Marion formation and hence to avoid confusion the name Marion was dropped for the lower division and it was renamed the Winfield concretionary limestone from the outcrops in the vicinity of Winfield, Cowley county, in southern Kansas.[2] Fourteen months later Dr. Keyes published the name "Winfield limestone," which he applied to a Cambrian formation found in the Mississippi valley near Winfield, Lincoln county, Missouri.[3] In 1900 Professor Harris and Mr. Veatch applied the very similar name of Winnfield limestone (spelled Winn) to a Cretaceous formation of northern Louisiana.[4] Clearly the Kansas usage of the name has priority, and Winfield is adopted as the name of this formation.

SUMNER STAGE.

The two upper formations of the Big Blue series (the Marion and Wellington shales) were classed together by Professor Cragin to form the Sumner division.[5] It was named after Sumner county in southern Kansas which includes nearly the entire breadth of its outcrop in that part of the state. This name is retained for this division, which is considered to have the rank of a stage.

Marion formation.—Buff thin-bedded limestones and shales form the principal part of this formation which is the latest Paleozoic one found on the Cottonwood Falls quadrangle. The

[1] JOUR. GEOL., Vol. III, 1895, p. 772.

[2] *Univ. Geol. Surv. Kan.*, Vol. II, Feb. 15, 1897, p. 64.

[3] *Proc. Iowa Acad. Sci.*, Vol. V, April 28, 1898, p. 60.

[4] *Geol. Surv. La.*, Report for 1899, Sec. II, p. 56.

[5] *Col. Coll. Studies*, Vol. VI, pp. 3, 9, 48.

lower part is composed of rather soft, porous, thin-bedded limestones and shaly layers to shales, containing near the base a considerable number of silicious geodes and occasionally some chert. Some fifty or sixty feet above the base is a buff limestone containing large numbers of small lamellibranchs, as *Pleurophorus subcuneatus* M. & H., *Bakewellia parva* M. & H., *Yoldia subscitula* M. & H., and other species, while about twenty feet higher is another similar limestone containing large lamellibranchs, as *Aviculopecten occidentalis* (Shum) Meek, *Myalina permiana* (Swallow) M. & H., and *Pseudomonotis Hawni* (M. & H.). A limestone containing *Pleurophorus* occurs in some localities near this horizon, which also contains large chert concretions.

The upper portion of the formation is composed mostly of thin buff limestones similar to those in the lower portion, alternating with a greater thickness of shales and marls, and in some localities contains beds of gypsum and salt. On Turkey Creek, south of the Smoky Hill valley and Abilene, a conglomerate stratum from fifteen to twenty feet in thickness occurs some 150 feet above the base of the formation, which was first described by Meek and Hayden in 1859.[1] To the northwest of the Cottonwood Falls quadrangle two beds of gypsum occur in this formation in Dickinson and Saline counties, both of which are worked. The lower one was named the "Solomon gypsum" by Dr. Grimsley,[2] and various outcrops occur up Gypsum Creek to Gypsum, as well as on Holland Creek, near Dillon. The higher bed is found in Greeley township, southeast of Salina, which was called the "Greeley gypsum" by Dr. Cragin,[3] while at Hope in the southeastern part of Dickinson county both strata of gypsum occur, separated by one hundred feet of shales and limestones. In southern central Kansas there are indications of a third horizon, forty feet above the Greeley gypsum, while the deposit in the southern part of the state, about four miles northwest of Geuda Springs, Sumner county, is in the upper part of the forma-

[1] *Proc. Acad. Nat. Sci. Philadelphia*, Vol. IX, p. 16, No. 9.

[2] *Univ. Geol. Surv. Kan.*, Vol. V, 1899, p. 61.

[3] *Col. Coll. Studies*, Vol. VI, 1896, p. 10.

tion.[1] In the southern part of the state the upper portion of the formation consists to a large extent of clay-shales of various colors, with some beds of limestone, gypsum, and rock salt. Its lithologic character, as it dips deeply below the surface to the westward, is shown by the well records to change from the variegated shales alternating with beds of limestone and gypsum to saliferous shales of bluish-gray to slate color alternating with massive beds of rock salt. It covers a large portion of the eastern two-thirds of Marion county, its lower part is quite well shown in the vicinity of the city of Marion, and for these reasons it was given the name "Marion formation."[2] On account of the terms "Marion flint" and "Marion concretionary limestone," Professor Cragin, in 1896, named this formation the "Geuda Salt-measures," from Geuda, Sumner county,[3] which name he withdrew during that year in favor of the "Marion formation."[4]

Wellington shales.—This formation consists largely of bluish-gray to slate-colored shales, but contains some red ones, and in the southern part of the state beds of impure limestone and calcareous shales, together with occasional beds of gypsum and dolomite. Limited saline deposits are reported, but no rock salt. Fossils are very rare, and, as far as the writer is informed, none have been found in the formation. In the Smoky Hill valley there are about two hundred feet of the Wellington shales, but they thicken to the south, and are reported as 450 feet in thickness in Sumner county, near the southern line of the state. Professor Cragin named and described these shales in 1896 from exposures in the vicinity of Wellington, the county seat of Sumner county.[5]

TABLE OF THE UPPER PALEOZOIC FORMATIONS OF KANSAS.

The formations just described, together with the succeeding ones of the Permian, have been arranged in the following table of the Upper Paleozoic formations of Kansas.

[1] See DR. GRIMSLEY'S account in *Univ. Geol. Surv. Kan.*, Vol. V, 1899, p. 69.

[2] JOUR. GEOL., Vol. III, 1895, p. 786.

[3] *Col. Coll. Studies*, Vol. VI, March, 1896, pp. 3, 9–16.

[4] *Am. Geol.*, Vol. XVIII, Aug., 1896, p. 132.

[5] *Col. Coll. Studies*, Vol. VI, pp. 3, 16.

CORRELATION OF THE CIMARRON SERIES.

In the earlier papers of the writer, the Cimarron series was referred provisionally to the Permian[1]; but later the discovery of Permian fossils as high as the Red Bluff formation, together with other data, apparently proves that at least the greater part of the series is of Permian age. Most of the fossils have been found by Professors A. H. Van Vleet and Charles N. Gould; the latter has described the horizons from which they were collected and given a list of three specific and three generic identifications of Permian vertebrates by Dr. Williston, which came from near the base of the Harper sandstone, and eleven genera of invertebrates identified by Dr. J. W. Beede. He states that the highest locality, which is in the Red Bluff formation, "has yielded some twenty species of invertebrates, several of which are of new forms."[2]

Dr. Beede, who has also published a note concerning these highest fossils, states that "they are mainly pelecypods with a species of brachiopod and a few gasteropods. . . . *Aviculopecten occidentalis* (Shum) Meek, is also present, and one other species bearing somewhat of a resemblance to it, but quite different from it in some respects, is also present. One of the common fossils is a biplicate terebratuloid, *Dielasma Schucherti* Beede, belonging to a group of this genus heretofore unknown in the American Permian. Mr. Schuchert informs me that it is very similar to a species of this genus described by Waagen from the Permian of Europe. . . . .

The presence of these fossils clearly demonstrates the Permian age of these rocks, coming as they do from very near to the top of the beds."[3] The description of these invertebrate fossils from the Red Beds by Dr. Beede has been published as an Advance Bulletin of the First Biennial Report of the Oklahoma Geological Survey.[4] The following new species are

[1] *Univ. Geol. Surv. Kansas*, Vol. II, 1897, pp. 89–92; *Kan. Univ. Quart.*, Vol. VI, 1897, pp. 150, 151; JOUR. GEOL., Vol. VII, 1899, pp. 354–6.

[2] JOUR. GEOL., Vol. IX, July, 1901, p. 339.

[3] *Am. Geol.*, Vol. XXVIII, July, 1901, pp. 46, 47.

[4] April, 1902, pp. 1–11, with one plate.

described: *Bakewellia Gouldii*, *Conocardium oklahomaensis*, *Aviculopecten Van Vleeti* and *Dielasma Schucherti*; *Aviculopecten occidentalis* is identified and, generically, specimens of *Naticopsis*, *Pleurotomaria*, *Schizodus*, *Lima* and *Pleurophorus*, all of which are from White Horse Springs, Oklahoma. Dr. G. I. Adams also states that Dr. Williston considers the vertebrate remains from the Harper sandstone "as equivalent to Cope's Lower Permian fauna from the Wichita beds of Cummins in northern Texas."[1] He further said, in discussing the age of the Red Beds of eastern Oklahoma, that "The age of that portion of the Red Beds which is in strike with the Permian of Kansas may confidently be expected to be found to be of Permian age. This is in accordance with the evidence already furnished by the vertebrate fossils. Above the Permian limestones in Kansas occur the Wellington shales, which are bluish and greenish-gray in color. They are probably represented southwestward by formations which are red. The succeeding formations are typical Red Beds, and have thus far yielded only Permian fossils."[2]

In a discussion of the "Relations of 'Upper Permian' to Triassic" Dr. Keyes has stated that "Prosser has been led to believe that the greater part of the Kansas 'Red Beds' are Triassic."[3] The above statement is erroneous, for previous to the publication of Dr. Keyes' paper my discussion of the Cimarron series in the Kansas report appeared under the heading of "The Upper Permian." At that time, however, I did not consider the evidence strong enough to justify their correlation with the Permian without a question.[4] This idea was expressed near the close of the section on "Correlation" in the following sentence: "On account of this dissimilarity in lithologic characters [between the Red Beds of Texas and Kansas] and the absence of fossils in Kansas and northern Oklahoma, together with the fact that there is yet no account of the careful tracing of any part of the Red-Beds across Oklahoma to Texas where their age

[1] *Am. Jour. Sci.*, 4th ser., Vol. XII, Nov., 1901, p. 383.

[2] *Ibid.*, p. 386. [3] JOUR. GEOL., Vol. VII, July, 1899, p. 339.

[4] See the table of classification in *Univ. Geol. Surv. Kansas*, Vol. II, Feb., 1897, p. 94.

could be determined by comparison with the fossiliferous terranes, the correlation of these rocks with either the Triassic or Permian is a matter of uncertainty."[1] In the later paper of that year I simply quoted the opinions of Dr. Williston, Professor Grimsley and Mr. Vaughan, without expressing any opinion, beyond the statement that "there is uncertainty as to their age,"[2] while in my paper succeeding that of Dr. Keyes' in the same number of the JOURNAL OF GEOLOGY it was stated that "The Paleozoic of Kansas closes with the Cimarron group or the Red Beds;"[3] following which was an account of the identification by Dr. Williston of *Eryops megacephalus* from the lower part of the Cimarron series, an amphibian described by Cope in the Permian of Texas.

THE PERMIAN QUESTION.

CORRELATION OF THE UPPER PALEOZOIC OF KANSAS WITH THE RUSSIAN PERMIAN.

Opinions of various geologists.—There is still a difference of opinion among American geologists in regard to the correlation of the Upper Paleozoic formations of Kansas with the Russian Permian. The JOURNAL OF GEOLOGY published in 1898, "A symposium on the classification and nomenclature of geologic time-divisions," in which Dr. Williston,[4] Professor Calvin[5] and Dr. Keyes[6] reported adversely both as to the identification of the Permian in Kansas and to its recognition as a period coördinate with the Carboniferous or Devonian; while Dr. William B. Clark stated that for the later divisions of the Paleozoic he should employ the chronologic terms Carboniferous and Permian.[7] Dr. Clark wrote me later as follows regarding this subject:

> I distinctly object to the abandonment of the term Permian for a major division and can see no just grounds for it since the division is one of importance in Europe and other portions of the world. To be sure, in America the Permian conditions are not as prominent, but I can see no reason on that ground for disturbing the geological column as it has come to be generally accepted.[8]

[1] *Ibid.*, p. 92. [2] *Kan. Univ. Quart.*, Vol. VI, Dec. (?), 1897, p. 150.
[3] *Loc. cit.*, Vol. VII, p. 354. [5] *Loc. cit.*, p. 353. [7] *Loc. cit.*, p. 341.
[4] *Loc. cit.*, Vol. VI, p. 343. [6] *Loc. cit.*, p. 352. [8] Letter of December 16, 1898.

Vertebrate fossils found in northern Texas led Professor E. D. Cope to the conclusion that the rocks were of Permian age and he stated that "The evidence now adduced is sufficient to assign the formation, as represented in Illinois and Texas, to the Permian."[1] The invertebrate fossils from the same beds were regarded by Dr. Charles A. White as indicating their Permian age.[2] The stratigraphy of the Upper Paleozoic formations of Texas was fully described by Professor W. F. Cummins, who referred them to the Permian.[3]

In recent years the following geologists have studied the Upper Paleozoic rocks of Oklahoma, Kansas or Nebraska and termed them Permian. Dr. James P. Smith who stated that "The lower Permo-Carboniferous strata of Kansas and Nebraska are probably also to be correlated with the Artinsk stage [basal Permian of Russia]."[4] Professor Cragin, who gave an extended account of "the Permian system in Kansas;"[5] Professor Wilbur C. Knight who wrote a similar paper on "The Nebraska Permian"[6] and showed from tables of distribution that "Of the forty-four genera of invertebrates known in the Kansas and Nebraska rocks, over three-fourths of them belong to the Permian of the Orient. The remainder are nearly all American genera and are chiefly pelecypods."[7] Prof. Knight has also stated that "From our present knowledge it seems advisable to refer the Red Beds of the Laramie Plains [Wyoming] to the Permian."[8] Dr. J. W. Beede, in his paper on "A Reconnaissance in the Blue Valley Permian"[9] described the Lower Permian as represented in Kansas north of the Kansas river and in southern Nebraska. And finally Professor Charles N. Gould and Doctor

[1] *Geol. Surv. Texas, Second Ann. Rept.*, 1891, p. 414.

[2] *Bull. U. S. Geol. Surv.*, No. 77, 1891.

[3] *Geol. Surv. Texas, Fourth Ann. Rept.*, 1893, p. 212.

[4] JOUR. GEOL., Vol, II, 1894, p. 194; and see pp. 188, 204. Also see *Proc. Am. Phil. Soc.*, Vol. XXXV, 1896, reprint pp. 11, 12, 24.

[5] *Col. Coll. Studies*, Vol. VI, 1896, pp. 1–49 and supplemented by one in the *Am. Geol.*, Vol. XIX, 1897, pp. 351–64.

[6] JOUR. GEOL., Vol. VII, 1899, pp. 357–75.

[7] *Ibid.*, p. 370. [8] JOUR. GEOL., Vol. X, 1902, p. 421.

[9] *Kan. Univ. Quart.*, Vol. IX, July, 1900 (1901), pp. 191–203.

Beede have shown from fossils, the Permian age of the Kansas-Oklahoma Red Beds.[1]

Another paleontologist, who is studying the fossils of the western Carboniferous writes me:

I don't believe that there is any Permian there at all, unless possibly the Marion and superjacent beds are Permian. I express the opinion with that qualification, (the possibility of the Marion being Permian), and another that the Kansas area *may* have been a shut-in basin and have retained its Carboniferous facies into Permian time.

Dr. Erasmas Haworth wrote me as follows:

I do not hesitate to say that I am most strongly opposed to the substitution of the term Oklahoman or any other for that of Permian. It looks now as though the whole of the Red Beds would be called Permian. Should this be done we will have a terrane which, along the southern line of Kansas, will be from 2,000 to 3,000 feet thick, or in other words as thick as the whole of the Coal-measures. This mass of earth is as different in all physical aspects from the Coal-measures as they are from any other terrane. It should be given a prominent place, but just how prominent I am not yet ready to express an opinion. I do not see how anybody can well settle the question of rank of the American Permian until all these questions are worked out, which work will necessitate an intimate examination of the territory lying between Kansas and Texas. I favor insisting on the use of the term Permian and let its rank stand as others have given it until somebody is ready to tell us in detail and in a connected way what we have in Kansas, Indian Territory, and Texas. As far as I can see the indications now are that the Permian ultimately, with the Red Beds included, shall be entirely separated from the Carboniferous.[2]

In 1891 Dr. Th. Tschernyschew, the former able director of the Russian Geological Survey and the authority on the middle and upper Paleozoic of Russia, in company with Professor H. S. Williams, examined the rocks as exposed along the Kansas river from Manhattan to Fort Riley. Their conclusions were reported as follows by Mr. Robert Hay: "While agreeing that the lower beds [at Fort Riley] are Permo-Carboniferous, they state that the upper beds — where the Phacoceras is — are decidedly Permian, the Russian professor assuring me that both

[1] GOULD, JOUR. GEOL., Vol. IX, 1901, pp. 337–41; BEEDE, *Am. Geol.*, Vol. XXVIII, 1901, pp. 46, 47; and *Adv. Bull. First Bien. Rept. Okla. Geol. Surv.*, 1902, pp. 1–11.

[2] Letter of December 16, 1898.

faunal and lithologic characters can be duplicated in the Permian of his own country."[1] The specimens of *Phacoceras* and other Cephalopods from Fort Riley and Junction, Kansas, were identified and described by Professor Alpheus Hyatt and came from the Fort Riley limestone. Therefore, according to the above statement Dr. Tschernyschew correlated the Fort Riley limestone and superjacent Paleozoic formations with the Permian of Russia.

Correlation of the Kansas and Texas beds.— Professor Cummins reported that:

> The *Phacoceras Dumblei*, Hyatt, has been found only along a very narrow horizon in the Texas Permian. . . . . This fact will assist materially in correlating the Texas and Kansas beds, as that fossil has been reported only from one locality in the Kansas area, where it is associated with the same fossils as in Texas. It is quite certain that the Fort Riley horizon is the same as the Wichita division of Texas, and is at the very top of the division.[2]

In ascending order the divisions of the Texas Permian as described by Professor Cummins are the Wichita, Clear Fork and Double Mountain;[3] while the Albany division[4] was left "as the top of the Coal-measures"[5] although the statement was made that "It may be that the Wichita and Albany divisions are but different facies of the same formation" for the Wichita division north of the Brazos river "occupies the same position, stratigraphically, as the Albany beds on the south."[6] Later Professor Cummins proved the correctness of the latter supposition and stated that he "found the fact well established that the Wichita and the Albany divisions were the same in time of deposition, and therefore the Albany must be abandoned both as to its name and the age to which I had previously referred it, and

[1] *Trans. Kan. Acad. Sci.*, Vo XIII, 1893, p. 38.

[2] *Trans. Texas Acad. Sci.*, Vol. II, 1897, pp. 97, 98. Also see D. W. JOHNSON, in *Bull. Sci. Lab. Denison Univ.*, Vol. XI, 1900, p. 223.

[3] *Geol. Surv. Texas, Second Ann. Rept.*, 1891, pp. 361, 373. *Fourth ibid.*, 1893, pp. 224–32.

[4] Prof. Hill has shown that the Albany division of Cummins is the same as the one named and described at an earlier date by Prof. Tarr as the Coleman. *Twenty-first Ann. Rept. U. S. Geol. Surv.*, Pt. VII, 1902, pp. 96, 97).

[5] *Ibid.*, p. 224. [6] *Ibid.*, p. 223.

the beds composing the division must be referred to the Wichita division of the Permian. Since the Wichita division is now made to include the area heretofore referred to as the Albany division, it becomes at once the most important and interesting part of the Permian in North America."[1] And he concluded with the statement that "it has been determined that the Albany division, with its numerous fossils, is but another facies of the Wichita division which is beyond question Permian."[2]

If Professor Cummins be correct in correlating the Fort Riley limestone with the top of the Wichita division of Texas it very decidedly supports the reference of the Upper Paleozoic formations of Kansas to the Permian. He had stated that all the typical localities of invertebrate fossils described by Dr. C. A. White were included in the Wichita division, "the greatest number of vertebrate fossils described by Professor Cope" and the fossil flora described by Dr. I. C. White;[3] while the *Phaceras Dumblei* "was taken from the very top of the Albany division."[4]

The fossil named and described by Professor Heilprin as *Ammonites Parkeri* which was reported from rocks of Carboniferous age in Wise county, northern Texas,[5] was referred to *Popanoceras* by Professor James P. Smith[6] who stated, on the authority of Professor Cummins, that the *Popanoceras Parkeri* beds are in the Strawn [Richland] division and therefore of the age of the Lower Coal-measures.[7] The occurrence of this type in the Texas beds, however, led Karpinsky in 1889 to write as follows: Since the Popanoceratidæ up to the present time have not been found in other countries in deposits which are older than the Permo-Carboniferous (in which the commonest Ammonites occur),

[1] *Trans. Texas Acad. Sci.*, Vol. II, 1897, p. 97. Also see JAMES P. SMITH, *Proc. Am. Phil. Soc.*, reprint, 1896, p. 13.

[2] *Trans. Texas Acad. Sci.*, Vol. II, 1897, p. 97.

[3] *Geol. Surv. Texas, Fourth Ann. Rept.*, p. 225. Also see *Trans. Tex. Acad. Sci.*, Vol. II, 1897, pp. 94, 95.

[4] *Geol. Surv. Texas, Fourth Ann. Rept.*, p. 223.

[5] *Proc. Acad. Nat. Sci. Philadelphia*, 1884, Vol. 36, pp. 53–5.

[6] JOUR. GEOL., Vol. II, 1894, p. 194; and see "Correlation Table" on p. 204.

[7] *Proc. Am. Phil. Soc.*, Vol. XXXV, 1896, reprint, p. 16 f *.

therefore in my opinion the Texas deposits must rather be assigned to the Permo-Carboniferous.[1]

In 1891 came Dr. C. A. White's description of "thirty-two species of invertebrates . . . . . from the Texan Permian," of which four Cephalopods belonging to the family *Ammonoidea* were recognized as new. It was stated that two of these types, *Waagenoceras Cumminsi* and *Popanoceras Walcotti*, "are so generally regarded as indicating the Mesozoic age of the strata containing them that if they alone and without any statement of correlated facts had been submitted to any paleontologist he would not have been warranted in referring them to an earlier period than the Trias if he had followed the usually accepted standard of reference."[2]

In conclusion Dr. White stated that "The evidence upon which the Texan strata have been referred to the Permian is fuller than that which has been adduced with regard to any other North American strata that have been so referred. That is, the evidence both of the vertebrate and invertebrate fossils is in favor of such reference, and the difference in the character of the strata from those of the underlying Coal-measures, although not great, is conveniently distinguishable;"[3] while he was inclined to consider the Texan Permian as of younger age than the Indian and Sicilian strata containing the commingled Mesozoic and Carboniferous forms which were described by Professors Waagen and Gemmellaro.

Waagen correlated the "Red sandstones and shales of Texas, with many remains of Vertebrates, *Amphibia* and *Reptilia* and *Goniatites Baylorensis*, *Hyattoceras Cumminsi*, *Medlicottia Copei* and *Popanoceras Walcotti*" with the "Weissliegendes and marl slate" which he put at the base of the magnesian limestone, that formed the upper division of his Permian system.[4]

Marcou stated "It is certain that the Wichita division belongs

[1] *Mém. Acad. Imp. Sciences St. Pétersbourg*, VII[e] Sér., t. XXXVII, No. 2, 1889, p. 93. Also see the correlation of the Texas deposits as shown in Table C, p. 94.

[2] *Bull U. S. Geol. Surv.*, No. 77, p. 31. [3] *Ibid.*, p. 38.

[4] *Mem. Geol. Surv. India, Palæ, India*, ser. xiii, "Salt-Range Fossils," Vol. IV, Pt. II, "Geological Results," 1891. Tabular View showing the relations of the Salt-Range Upper-Palæozoic strata to the deposits of other countries, op. p. 238.

to the Dyas (Permian)"[1]; while in considering the list of fossils given by Cummins he said: "It is a fauna related with the Russian fauna of the Artinsk beds, and may be considered as the American representative of a part of the Russian Dyas (Permian)."[2]

Professor James P. Smith stated that "the Ammonite-bearing beds of northern Texas, described by Dr. C. A. White . . . . . belong above the Artinsk stage, and in the true Permian, and are probably of the same age as the middle division of the *Middle Productus* limestone of the Salt Range [India]."[3]

Dr. Keyes in discussing the parallelism between the Texas and Kansas beds said, "The Double Mountain beds are, in a broad way, manifestly approximately equivalent to Cragin's Cimarron series. This leaves a considerable part of the Clear Fork beds representing the Chase and Marion of Kansas."[4] Professor de Lapparent considered that in northern Texas the Uralian with *Productus cora* and *Athyris subtilita* is succeeded conformably by 300 meters of sandstones and shales, occasionally calcareous, in which the red color predominates, the base of which appears to belong in the Artinsk.[5] He stated that the red gypsiferous beds with *Pleurophorus* which in the western part of Texas surmount the Wichita formation belong in the Upper Permian.[6] Finally, Dr. Frech puts the Wichita and Clear Fork beds in the Palaeo-Dyas and the Double Mountain beds in the Neo-Dyas[7] and states that the Ammonoids described by Dr. White — *Medlicottia Copei*, *Popanoceras Walcotti* and *P.* (*Hyattites*) *Cumminsi* have their nearest relatives in the marine Dyas of Sicily.[8]

Provisional correlation of the Kansas formations.—The above statements indicate clearly enough the differences in opinion among geologists more or less acquainted with the Upper Paleozoic formations of the Great Plains, regarding their correlation. It is to be noted, however, that there is a more general agreement regarding the Permian age of the Texas deposits, and if Professor

[1] *Amer. Geol.*, Vol. X, 1892, p. 370. [2] *Ibid.*, p. 371.

[3] JOUR. GEOL., Vol. II, 1894, p. 194; and see "Correlation Table" on p. 204.

[4] JOUR. GEOL., Vol. VII, 1899, p. 325.

[5] *Traité de Géologie*, 4th ed., 1900, p. 981. [6] *Ibid.*, p. 994.

[7] *Lethaea palæozoica*, Bd. II, 3 Lief., 1901, p. 514. [8] *Ibid.*, p. 515.

Cummins has correctly correlated the Fort Riley limestone with the Texas deposits it furnishes a strong argument in favor of referring the Upper Paleozoic formations of Kansas to the Permian.

Furthermore, the number of American geologists who believe that these Upper Paleozoic formations should be correlated with the Permian and given the rank of a period or system is probably still smaller than the number of those who would retain the name Permian but classify it as the upper series of the Carboniferous. The writer had hoped to carefully study the fossils of these formations and to present their complete evidence regarding these questions, but other duties have prevented the execution of this plan. It has appeared to me, however, that the weight of evidence favored correlating the upper formations with the Permian.

Whether the Permian should be assigned the rank of a system coördinate with the Carboniferous or regarded as the upper subdivision of it is not quite clear, and the line of division between the Permian and the Carboniferous is in doubt, as indicated on the chart p. 730. The opinions of some of the leading European students of the Upper Paleozoic, who regard the Permian as a distinct system and correlate certain American formations with it, has seemed to the writer sufficient authority for provisionally regarding it as a system, which was done in the table of classification opp. p. 704. It is probable, however, that the U. S. Geological Survey will retain the name Permian, but will classify it as the last series of the Carboniferous system.

Conclusions of Dr. Keyes.— No one has, perhaps, insisted as strenuously as Dr. C. R. Keyes that the name Permian should be dropped from American geology. In 1897 he attended the sessions of the International Congress of Geologists at St. Petersburg and participated in the excursions to the Carboniferous and typical Permian of Russia. Later he prepared a paper on the "American homotaxial equivalents of the original Permian," and quotations from this cannot be regarded as from one favoring the retention of the name "Permian." Regarding the lithologic features Dr. Keyes said :

The original Permian strata are indistinguishable, lithologically, from the so-called Permian of Kansas. In both there are the same gray and variegated sandy shales and marls, passing locally into sandstones, that are often copper-bearing. Occasionally there are present thin bands and beds of buff earthy limestone. Gypsum is abundantly developed in the beds and interspersed everywhere through the rocks. Saline shales are of not infrequent occurrence. On both continents all these pass upward into "Red Beds" that are almost destitute of fossils.

And in another paragraph is a striking statement that "In the Russian district one finds it difficult to imagine that he is not wandering through some part of Kansas. Only the presence of the Russian peasant or sudden contact with a village of the steppes dispels the illusion."

Secondly, under the heading, "Range of faunas," Dr. Keyes reported as follows regarding the fossils:

The succession of faunas appears to be essentially the same in the Russian Carboniferous and Permian as in the Mississippi valley. The composition of each of the faunas is also strikingly comparable. The most noteworthy feature of the organic remains, viewed as a whole, is the gradual replacement of a purely marine type by a shore and brackish water phase, as the change from open sea to closed water conditions took place, and finally to those in which life could not exist. The most prominent characteristic of the biotic change from a Carboniferous phase to a Permian one seems to be the replacement of a predominantly brachiopod fauna by one in which lamellibranchs formed the preponderant element.[1]

While in another article Dr. Keyes said: "In lithological and faunal characters the rocks are so nearly alike that it is difficult to fancy that in the Urals one is on the opposite side of the earth from our Iowa and Kansas beds."[2]

Under the general heading, "Comparison of the Russia and Mississippi Valley Carboniferous," and subheading, "Stratigraphic parallelism," Dr. Keyes stated that "In Russia and in the Mississippi valley the general geological sections of the Upper Paleozoic are remarkably alike. The basins occupied by these rocks are very nearly of the same size. As already stated in the first-mentioned area, the Permian very greatly predomi-

[1] JOUR. GEOL., Vol. VII, 1899, p. 334.

[2] "Permian Rocks of Eastern Russia," in *Proc. Iowa Acad. Sciences*, Vol. VI, 1899, p. 231.

nates as the surface rock; in the last-named, the Coal-measures."[1] While the above paragraph is followed by the following "Comparison of general sections" in Russia and the Mississippi valley, which may evidently be regarded as Dr. Keyes's idea of the correlation of the upper Paleozoic rocks of the central United States and Russia.

Russia.	Character of Terranes.	Mississippi Valley.
Tartaran, Permo-Trias, or Upper Permian, P_3	Shales and marls, red and variegated, shaly sandstones; fossils rare; "Red Beds"	Cimarron Series
Middle Permian, P_2	Limestones, some dolomitic, separated by calcareous marl	(Marion li.)
Lower Permian, P_1-b	Shales (only 200 feet thick in Kama Valley)	——— ? } Series
Upper Permo-Carboniferous (base of original Permian) CP_c	Limestone, heavy dolomitic	(Chase li.)
Artinsk, CP	Shales, sandstones, some thin limestones	(Neosho) (Cottonwood) (Wabaunsee) } Series
Upper Carboniferous, C_3	Limestones and shales, highly fossiliferous	Missourian Series[2]

Finally, in his "Recapitulation" it is stated "That while we have in America a great succession of deposits identical in all essential respects to the original Permian of Russia, the two great basins merely had similar histories that are not necessarily connected and doubtless were wholly independent of each other and unrelated."[3]

Dr. Keyes's description and comparison of rocks and faunas apparently support the correlation of the Upper Paleozoic of the Great Plains with the Permian of Russia, providing one follows

[1] Jour. Geol., Vol. VII, 1899, pp. 331, 332.

[2] *Ibid.*, p. 332; *Proc. Iowa Acad. Sciences*, Vol. VI, p. 230.

[3] Jour. Geol., Vol. VII, p. 341; *Proc. Iowa Acad. Sciences*, Vol. VI, p. 231.

the rules of correlation generally observed by geologists.[1] The evidence is apparently about as conclusive as for other systems in this country which are correlated with the Carboniferous, Devonian, or Silurian of Europe. Apparently the main point of Dr. Keyes' contention is "That [the] Permian, as originally proposed, applies to a provincial series, and, according to our usual standard, has, at best, a taxonomic rank below that of system."[2] Yet he states it is probable that its main subdivisions will be elevated "to the rank of series," which, instead of causing the name Permian to be dropped, as he suggests, will more probably leave it with the rank of a system as originally defined by Murchison. A geologist familiar with the Kansas formations wrote as follows concerning the provincial series question: "Grant, as Keyes maintains, that Permian is the name of a provincial series, then where a similar series is found with similar fossils the same name ought to be given. All our names were names of provincial series at first. What was Devonian but the name of a series of rocks in Devonshire, England? When found in New York, by this argument, they should be called New Yorkian or some other American name."

The conclusions of Dr. Frech.— On the other hand, the conclusions of Dr. Fritz Frech, the eminent professor of geology and paleontology in the University of Breslau, may be considered. He has carefully studied, both in the field and laboratory, the Permian of Germany and Russia and examined in the field the Permian of the United States, at least as shown in the Grand Canyon and near Salt Lake City, Utah.[3] Dr. Frech gives these rocks the rank of a system, which is also the usage of Dr. Kayser, of the University of Marburg,[4] but instead of Permian he

[1] For instance, if his account be compared with the list of physical and biotic methods of correlation given by Professor Gilbert at the Washington meeting of the International Congress of Geologists, it will be seen that several of the methods are fulfilled (Congrès Géologique International, *Compte Rendu*, 5me session, Washington, pp. 68, 69).

[2] *Loc. cit.*, p. 341; and p. 231.

[3] See *Congrès Géologique International, Compte Rendu*, 5me Ses., Washington, 1891, 1893, p. 481; and *Lethaea palæozoica*, Bd. II, 3 Lief., 1901, p. 515.

[4] See *Text-Book of Comparative Geology*, by E. KAYSER, translated and edited by Philip Lake, 1893, p. 164.

uses the later name of Dyas proposed by Marcou on account of the sharply marked separation of the system into two divisions in Germany.

Dr. Frech's classification of the Upper Paleozoic of Kansas is as follows:

Upper Dyas	Red shales and clays.
	Marion.
Lower Dyas	Chase.
Transition to Carboniferous (distinct line fails.)	Neosho.
Upper Carboniferous	Cottonwood beds.
	Wabaunsee.[1]

Later Dr. Frech reviewed Professor Cragin's classification of the Permian, and termed the Cimarron series the "Neo-Dyas," and the Big Blue series the "Paleo-Dyas."[2] He stated that the Dyas equaled the Permo-Carboniferous plus the Permian of many authors, and that by general agreement at the St. Petersburg International Congress of Geologists the names Paleodyas (=Permo-Carboniferous) and Neodyas (=Zechstein) are employed.[3]

Under the discussion of the boundary line between the Dyas and Carboniferous Dr. Frech said: The dividing line between the Carboniferous and Dyas formations cannot be drawn with full certainty in every region, since especially in the Dyas the development of the local flora is nearly always the rule, and decisive differences do not exist in the Brachiopod fauna.

Yet an agreement seems to be gradually forming everywhere. . . . . Where the characteristic Dyas bivalves (*Pleurophorus*, *Schizodus*, *Bakewellia*, *Pseudomonotis*) appear in masses (Kansas), there cannot be any doubt about the dividing line.[4] Under the description of the Dyas of the northern hemisphere and the Arta stage of Russia, as Dr. Frech prefers to call the Artinsk, he said: That the animal remains of the Permo-

[1] *Lethaea palæozoica*, Bd. II, 2 Lief., 1899, p. 378, as translated above.

[2] *Ibid.*, 3 Lief., 1901, p. 514. [3] *Ibid.*, p. 453 f.

[4] *Ibid.*, pp. 490, 491. I am greatly indebted to Charles W. Mesloh, associate professor of Germanic languages and literatures in the Ohio State University, who very kindly translated for me several pages of Dr. Frech's description of the Dyas.

Carboniferous are in general more nearly related to the Carboniferous than the Zechstein, finds its explanation in the poverty of the species of the inland seas. The Arta stage occupies a large space on the western slope of the Ural mountains from the Arctic ocean to the Kirghiz Steppe and the Donetz River, and was correctly classified with the Dyas by older investigators (Pander). The plant remains described by Schmalhausen speak quite decidedly for a comparison with the western Rothliegende[1] Murchison considered the Arta sandstone the Millstone grit, while the modern Russian authors mostly call it an intermediary stage from the Carboniferous to the Dyas, Permo-Carboniferous. If the latter assumption were correct, then the Cusel and Lebach strata would also have to be regarded as transitional from the Carboniferous to the Zechstein, *i. e.*, the most important and best known part of the formation would become a transition and only the equivalent of the German Zechstein would be designated as Permian.[2]

Usage of Russian geologists.—Among the recent Russian geologists who have described transitional deposits between the Carboniferous and Permian systems, may be mentioned the following: Krotow, who in 1888 described the Permo-Carboniferous and Permian on the western slope of the Urals in the region of Tscherdyn and Solikamsk.[3] Th. Tschernyschew, in 1889, described the Permo-Carboniferous of the western slope of the central Urals, which he lettered C P, and gave as composed of the Artinsk (C Pg), and superjacent Dolomitic limestone (C Pc), the latter forming the base of Murchison's Permian system.[4] Krasnopolsky, the same year, described the Permo-Carboniferous and Permian deposits of another portion of the western Urals,[5] which was followed two years later by a further description.[6] Stuckenberg, in 1890, described the Permo-Carboniferous of another region, which he gave as composed in ascending order

[1] *Ibid.*, pp. 493, 494.

[2] *Ibid.*, p. 493, f. 2.

[3] *Mém. Comité Géologique*, Vol. VI, pp. 553–9.

[4] *Ibid.*, Vol. III, No. 4, Blatt 139, pp. 356–66.

[5] *Ibid.*, Vol. XI, No. 1, Blatt 126, pp. 506–18.

[6] *Ibid.*, No. 2, 1891, pp. 28–30.

of the Artinsk and Kungur stages.[1] Sibirzev, in 1896 carefully described the Permian deposits near Nishny-Novgorod on the Volga, together with those of the Permo-Carboniferous farther to the west;[2] while Stuckenberg two years later described in a similar manner the Permo-Carboniferous and Permian formations of the Kama basin.[3]

Since then Dr. Keyes has very clearly summarized the Russian classification of the Upper Paleozoic terranes of eastern Russia in the following table:[4]

Terrane.	Symbol.	Character.
Tartaran	PT or P_3	Shales and marls, "Red Beds," very few fossils.
Zechstein (in part.)	P_2	Marls, limestones, and sandstones.
.....	Pb	Sandstones, shales, and marls with nodular limestones.
.....	C Pc	Dolomitic limestones (base of Murchison's Permian).
Artinsk	C Pg	Shales, shaly sandstones. This and next terrane above are called Permo-Carboniferous.
.....	C_3	Limestones.

Dr. Keyes states that following "the so-called true Carboniferous of the Urals . . . . are the transition faunas to the Permian, according to the Russians, and by them called Permo-Carboniferous. The two members which comprise it contain, as pointed out by Tschernyschew, very nearly the same organic forms, consisting largely of lamellibranchs, gasteropods, and brachiopods. The lower terrane, termed the Artinsk is notable for the ammonites that are found in it, which the author just mentioned compares with those lately found in the Texas Permian. . . . .

"The bottom terranes of the Permian, as now recognized by the members of the Russian geological survey, present a great paucity of fossils. The forms are chiefly lamellibranchs, yet in some layers are fragmentary plants.

"The median part of the Permian carries what has been regarded as the typical German Zechstein fauna.

[1] *Ibid.*, Vol. IV, No. 2, Blatt 138, pp. 111–14.

[2] *Ibid.*, Vol. XV, No. 2, Blatt 72, pp. 242–65.

[3] *Ibid.*, Vol. XVI, No. 1, 1898, pp. 309–21.

[4] JOUR. GEOL., Vol. VII, 1899, p. 330.

"About the upper terrane there is much dispute as to age. The Russian geologists are about equally divided. Amalitzky considers it Permian. By others it is regarded as Triassic. Fossils occur rarely. Those found are chiefly lamellibranchs."[1]

OPINIONS OF OTHER EUROPEAN GEOLOGISTS.

There are other noted European geologists, however, whose conclusions are in general accord with those of Dr. Frech.

Waagen, in his magnificent work on the geological classification of the Upper Paleozoic rocks of the Salt-Range in northern India, ranked the Permian as a system which he divided into the three following groups, arranged in ascending order: Permo-Carboniferous, Rothliegendes and Magnesian limestone. He published a table showing the correlation of the Upper Paleozoic strata of the Salt-Range with similar deposits of other countries on which the "red sandstones and shales of Texas," containing vertebrates and invertebrates which have been described by Cope and White, were correlated with the lower part of the Magnesian limestone, or upper group of his Permian system. The "limestones and shales, with *Pseudomonotis hawni* (——*speluncaria*) of Kansas, red gypsum beds of Texas"[2] were regarded as equivalent to the remaining portion of the Magnesian limestone group and consequently represent the upper part of the Permian system.

De Lapparent, in the last edition of his comprehensive treatise of geology, gives the Permian the rank of a system[3] to the lowest stage of which, the Artinskien or Autunien, he refers the Neosho, Chase and Marion terranes of central Kansas. It is stated that it would be difficult to class elsewhere than in the Artinskien, the Neosho and the Chase, although there may be a doubt regarding the correlation of the Marion.[4] On his table of "Synchronism of Permian assises," beds with *Pleurophorus* and with *Pseudomonotis* of Kansas are given as in the Thuringien or Upper Permian stage,[5] while on the following page it is stated

[1] *Ibid.*, pp. 330, 331.

[2] *Mem. Geol. Surv. India, Palæ.*, India. Series 13, Salt-Range Fossils, Vol. IV, Pt. II, Geol. Results, Calcutta, 1891, op. p. 238.

[3] *Traité de Géologie*, 4th ed., Pt. II, 1900, pp. 759–963.

[4] *Ibid.*, pp. 980–1. [5] *Ibid.*, p. 993.

that in the Upper Permian is, perhaps, also the horizon of the upper limestones and shales of Kansas with *Pseudomonotis Hawni*, which surmount 75 meters of variously colored shales and marls, with gypsum (assise de *Marion* de M. Prosser).[1]

It is to be noted, however, that de Lapparent is in error in correlating the sandstones and shales of Nebraska with the lower part of the Penjabien or Saxonien, which he classifies as the Middle Permian.[2] Such a classification puts the Nebraska City beds at least above the Neosho and Chase, as is clearly indicated on his table of synchronism, while as a matter of fact it has been shown by Dr. Beede and the writer that they are probably equivalent "to the Topeka limestones and Osage shales of the Kansas river section, which form the upper part of Professor Haworth's Shawnee formation of the Upper Coal-measures."[3] The rocks included between the top of the Shawnee formation, which is marked by the base of the Burlingame limestone, and the top of the Chase stage have an approximate thickness of 950 feet in eastern central Kansas, which gives an idea of the stratigraphic error when the Nebraska City beds are assigned to a position above the Chase stage.

In discussing the rank of the Permian de Lapparent wrote: The marine types of the Permian, scarcely known until recent years, show in Asia as in the United States greater and greater development. Finally, the well confirmed discovery of Ammonites with arborescent septæ gives to the pelagic fauna of the period a special character, at the same time that by the first appearance of true reptiles the terrestrial fauna shows a higher order than that of the preceding period. Therefore, we, agreeing with the excellent arguments of Neumayr in his *Erdgeschichte*, raise to the rank of system this last division of Primary time.[4]

Finally, from among the other famous European geologists who rank the Permian as a system and have written in support

[1] *Ibid.*, p. 994. [2] *Ibid.*, pp. 986–93.

[3] JOUR. GEOL. Vol. VII, Aug., 1899, p. 346. Also, see PROSSER, *ibid.*, Vol. V, March, 1897, p. 148; and BEEDE, *Kan. Univ. Quart.*, Vol. VII, Oct., 1898, Series A. p. 231; and *Trans. Kan. Acad. Science*, Vol. XVI, 1899, p. 70.

[4] *Ibid.*, p. 964.

of this proposition may be mentioned the following: Credner,[1] Prestwich,[2] Neumayr,[3] Sir Archibald Geikie,[4] Ed. Suess,[5] and Karl v. Zittel.[6]

CHARLES S. PROSSER.

COLUMBUS, OHIO,
June, 1902.

The question as to whether the Alma limestone should be substituted for the Cottonwood limestone on account of the earlier name of Cottonwood Creek beds in Texas was submitted to the U. S. Geological Survey Committee on Formation Names and under date of October 29, 1902, Dr. C. Willard Hayes has sent me the following report of the committee:

> This committee approved the name *Cottonwood limestone* at its meeting March 29, 1902, and at that time considered the priority of *Cottonwood Creek beds, Texas*. It decided at the time that, although the latter name had priority of usage, it probably was not a clearly-defined formation but merely a bed of unmapable dimensions. Also that inasmuch as *Cottonwood Creek beds* has not occurred in literature since its first usage in 1893, and whereas *Cottonwood* (*Cottonwood Falls*) *formation* has been used thirteen times since its first usage in 1894, the latter name has acquired a place in literature on the grounds of prescription. The committee therefore decided to adhere to its former decision in favor of *Cottonwood limestone*."

In compliance with the above decision the writer withdraws the name Alma limestone and retains Cottonwood limestone as the name of the Kansas formation.

C. S. P.

October 31, 1902.

[1] *Elemente der Geologie*, 6th ed., 1887, pp. 382–507.

[2] *Geology, Chemical, Physical and Stratigraphical*, Vol. II, 1888, pp. 8–131.

[3] *Erdgeschichte*, Bd. II, 1890, pp. 37–199.

[4] *Text-Book of Geology*, 3d. ed., 1893, "The Geological Record," op. p. 679 and p. 841.

[5] *La face de la terre*, translated by EMM. DE MARGERIE. T. II, 1900, p. 407.

[6] *History of Geology and Palæontology*, translated by MARIA M. OGILVIE-GORDON, 1901, p. 453.

ON SOME GLAUCOPHANE AND ASSOCIATED SCHISTS IN THE COAST RANGES OF CALIFORNIA.[1]

THE blue amphibole or glaucophane schists of the California Coast Ranges, with which are genetically associated actinolite and garnet schists, have been objects of considerable geologic interest since they were first observed in 1877. They have been cited by Mr. H. W. Turner,[2] Dr. H. W. Fairbanks,[3] and by others from many parts of the Coast Range mountains, throughout which they are abundant.

The schists occur to a large extent as rather massive isolated outcrops, and, in general, do not show their schistose structure except upon a near examination. They vary in texture from layer to layer; a hard, compact quartzose sheet being succeeded by a wrinkled, elastic, micaceous layer, which may be followed by a dense massive variety containing but little mica. These schists are for the most part entirely crystalline, and are principally characterized by the abundance of blue amphibole or glaucophane, which they contain. Whether this blue amphibole is mainly glaucophane, crossite or riebeckite the writers have not determined. There appear to be at least two varieties of the blue amphibole present in the series, one with a wide angle between the optic axes and strong double refraction, and another with a very narrow angle and weak double refraction. For the sake of convenience, however, and in accordance with the general practice, the blue amphiboles will be referred to in this paper as glaucophane.

[1] The writers are indebted to Dr. J. P. Smith, of Stanford University, for assistance and advice.

[2] "Notes on Some Igneous, Metamorphic and Sedimentary Rocks of the Coast Ranges of California," H. W. TURNER, JOUR. GEOL., Vol. VI, p. 488 *et seq.*; "The Geology of Mount Diablo, California," H. W. TURNER, *Bull. Geol. Soc. Am.*, Vol. II, p. 385.

[3] "The pre-Cretaceous Age of the Metamorphic Rocks of the California Coast Ranges," H. W. FAIRBANKS, *Am. Geol.*, Vol. IX, p. 160; "Notes on a Farther Study of the pre-Cretaceous Rocks of the California Coast Ranges," H. W. FAIRBANKS, *Am. Geol.*, Vol. XI, pp. 70–73.

Of less importance though widely distributed and intimately associated with the glaucophane is the light green actinolite schist which occurs with the glaucophane schist in irregular layers and masses. Both of these schists have garnets abundantly developed in them.

Dikes of serpentinized peridotite and also of diabase are commonly found in apparent association with the schists. It was on such an association that Dr. F. L. Ransome[1] based his hypothesis that the Angel Island glaucophane schist is the result of the contact action of fourchite and peridotite intrusions in the Golden Gate or Franciscan sandstones. Ransome's conclusions are questioned, however, by Turner,[2] who says: "It is yet to be demonstrated that these schists are the result of contact metamorphism."

In a short note in his paper on metamorphism, Professor C. R. Van Hise[3] refers to the glaucophane schists of the northern end of Calaveras Valley, in Alameda county, as resulting from dynamic agencies, and says they are formed from igneous rocks by crushing.

The writers have examined several localities where the schists occur, and where their relationship with accompanying rocks is clear. The principal ones are four in number: one about two miles southwest of Healdsburg, Sonoma county, one at Camp Meeker, Sonoma county, one mentioned by Van Hise in the northern end of Calaveras Valley, Alameda county, and one on Tiburon Peninsula, Marin county, in which the lawsonite described by Ransome[4] occurs. Besides these, many smaller exposures have been studied between Healdsburg and San Luis Obispo county, and especially in the region around the bay of San Francisco.

[1] "The Geology of Angel Island," F. LESLIE RANSOME, *Bull. Dept. of Geol. Univ. of Calif.*, Vol. I, No. 7, p. 211.

[2] *Loc. cit.*, p. 491.

[3] "Metamorphism of Rocks and Rock Flowage," C. R. VAN HISE, *Bull. Geol. Soc. Am.*, Vol. IX, p. 313.

[4] "On Lawsonite, a New Rock-Forming Mineral from the Tiburon Peninsula, Marin county, California," F. LESLIE RANSOME, *Bull. Dept. Geol., Univ. of Calif.*, Vol. I, No. 10, p. 311.

Healdsburg.—At Healdsburg the schist area is nearly a mile wide and more than four miles long. The thickness of the schist is several hundred feet, though no exact measurements have been made. From about half a mile south of the Junction Schoolhouse, which is two miles southwest of Healdsburg, the schists form a range of hills which extend in a general northwesterly direction for several miles. In the southern end of this area the schists are in contact with serpentine, and overlie a boss or laccolite of it. The contact is clear and unmistakable, as the rocks stand up above the soil, and hand specimens may be secured which show the parting between the schist and serpentine in a single fragment. In the serpentine boss is an irregular mass of gabbro—possibly a result of magmatic differentiation. In addition there are at least three serpentinized dikes in the schist area northwest of the Junction Schoolhouse, and also a small outcrop of diabase.

With the exception of one place where it grades into shale, the schist is entirely crystalline, and is composed mainly of glaucophane, actinolite, garnet, epidote, and various light-colored micas. Some layers are very quartzose and are composed mainly of quartz, glaucophane, garnet, epidote and a little white mica. The schists vary much in texture and mineral composition, but are easily recognized, as there are no other rocks like them in this locality.

South of the Junction Schoolhouse a fragment of actinolite schist was found in the serpentine, and its plane of schistosity makes a large angle with the planes of neighboring masses of schist. It is clearly an inclusion and points definitely to the serpentine being intrusive in and younger than the schist. Ransome, in his paper on the geology of Angel Island, mentions similar inclusions in the serpentine there.[1]

About a quarter of a mile southwest of the Junction Schoolhouse the schists appear to be overlain unconformably by Golden Gate or Franciscan[2] sandstones. This relation is not entirely

[1] *Loc. cit.*, p. 225.

[2] As the Franciscan or Golden Gate rocks are unfossiliferous, their identification away from the type localities is based on lithologic features and field relations, and is consequently uncertain.

certain, however, as the rocks may have been faulted into their present position. About two miles north of the Junction Schoolhouse, on the eastern flanks of the hills, are jaspers intruded by a serpentinized dike which has apparently had but little metamorphic effect.

In a hillside cut on the Healdsburg road about half a mile east of the Schoolhouse, there is an excellent gradation from slightly altered shale to entirely crystalline glaucophane and actinolite schist. Specimens can be collected showing every degree of alteration. Thin sections of the least altered shale show incipient development of glaucophane in crystalline tufts and radiate aggregates.

Camp Meeker.— At Camp Meeker, Sonoma county, about twenty-five miles southwest of Healdsburg, glaucophane and actinolite schists are developed over an area which appears to be at least a mile wide and several miles long, though the limits were not determined.

Intrusive in the schist are small dikes of a pyroxene rock which are themselves somewhat schistose, and have glaucophane, actinolite, chlorite and mica developed in them. On each side of these dikes the schist is of the normal glaucophane type and contains glaucophane, actinolite, garnets and white mica. Northeast of the schist area is a mass of serpentine, but at no point examined was the relation between the two rocks clearly shown.

About half a mile north of Camp Meeker there is a gradation from schist to shale in a distance of about three hundred feet. *The shale is hard and wrinkled*, and contains some secondary mica, but no glaucophane or actinolite.

Tiburon.—The glaucophane schist area on the Tiburon peninsula is about two hundred yards wide, and extends more or less continuously from Tiburon to north of Reed's station. Northeast of the schist is serpentine which caps the hills; and southwest are sandstones and shales. Near Reed's station, however, there is a small area of the sandstone and shales, which, on the surface, lies between the schist and the serpentine, and is in contact with the serpentine. At the immediate contact the shale is somewhat hardened but is unaltered at a distance of three feet.

Calaveras Valley.— In the northern end of Calaveras Valley, northwest of Mount Hamilton, in Alameda county, there is an area of glaucophane and related schists, which can best be studied in the canyon of the Arroyo Hondo. There are two series of glaucophane-bearing rocks in this locality; one a massive crystalline rock, one facies of which is an eclogite containing, principally, garnet, omphacite, glaucophane and actinolite. The other facies is a medium grained, light colored, banded rock composed principally of quartz, glaucophane, garnet, and white mica. The garnets are in the form of very small crystals which are included in the quartz and glaucophane.

The other series of glaucophane-bearing rocks overlies this massive one unconformably, and consists of thin bedded sandy shales having a vertical dip and a northwesterly strike. They are much contorted, however, and are hard and schistose in places. These beds are unfossiliferous, but are overlain unconformably by Lower Miocene sediments. They resemble to a large extent the sandy shales of the Golden Gate or Franciscan series, and it seems probable that they belong with those rocks. Glaucophane is developed in them irregularly, one bed being blue with it, while the adjoining one on either side may contain but little glaucophane. White mica is developed in these beds in many places, and narrow quartz veins are common.

In the southern end of the canyon are masses of serpentine, but the contacts between them and the adjoining rocks are not exposed.

In contact with the massive banded rocks is a hard, heavy, compact, greenish rock, with bands and stripes of glaucophane plentifully distributed through it. It may be an altered serpentine, but thin sections of it show no definite minerals. It is apparently a dike intrusive in the banded rock, but it has probably been altered since, and may have been subjected to the same agencies that produced the banded rock.

Conclusions.— No one explanation seems to satisfactorily account for the many different aspects and occurrences of the glaucophane and related schists. That there has been some development of glaucophane at the contact of basic igneous

masses seems certain. It seems improbable, however, that the main portion of the normal glaucophane and actinolite schists is a result of contact action. That the schists have not resulted from contact action by peridotite masses seems probable, for at some points the same masses have certainly produced but slight alteration in adjoining sandstones and shales, and the thickness and character of the schists is such that they could only have been produced by metamorphosing agents acting on a large scale. It seems difficult to believe, also, that the schists could be formed by serpentine dikes which are smaller than the schist masses themselves. Besides, the inclusions of schist in the Healdsburg and Angel Island serpentines render it almost certain that the schists are the older of the two rocks. In addition, the evidence points to the massive glaucophane rocks and normal schists being older than the Golden Gate or Franciscan series of rocks, for the schists are unconformably beneath what appears to be the Golden Gate or Franciscan rocks in the Calaveras Valley, and they probably have similar relations at Healdsburg. Finally, serpentinized dikes are frequently found intrusive in Golden Gate or Franciscan rocks, while at Mount Diablo,[1] near Gilroy,[2] and in San Luis Obispo county,[3] there are serpentine dikes intrusive in the Knoxville beds. This would of course make the dikes younger than the schists, if the schists are older than the Golden Gate or Franciscan series.

In some cases the schists have been formed directly out of sedimentary rocks, and probably in some cases out of tuffs or other igneous material. The writers have observed cases in which basic igneous dikes have had glaucophane and other secondary minerals developed in them, and have become more or less schistose.

It can hardly be doubted that glaucophane schists have been developed in rocks of different ages, and older than the Knoxville. It seems probable, also, that there is a series of

[1] *Loc. cit.*, p. 390.

[2] Communicated by Dr. J. P. Smith, Stanford University.

[3] "The Stratigraphy of the California Coast Ranges," H. W. FAIRBANKS, JOUR. GEOL., Vol III, p. 428.

glaucophane schists older than the Golden Gate or Franciscan, and the possibility suggests itself that these may be but isolated outcrops of extensive masses which underlie the Coast Ranges.

The only hypothesis that seems to satisfactorily explain the occurrences of these rocks is that they are the result of dynamic agencies, and may or may not be the products of widespread regional metamorphism.

EDWARD HOIT NUTTER,
WILLIAM BURTON BARBER.

STANFORD UNIVERSITY, CALIFORNIA,
May, 1902.

THE GEOLOGIC RELATIONS OF THE HUMAN RELICS OF LANSING, KANSAS.

UNDER the title "A Fossil Man from Kansas," Professor Williston announced in *Science* of August 1, the discovery of human remains in alluvium near the mouth of a ravine opening on the flood plain of the Missouri river near Lansing, Kansas. He gave a careful description of the circumstances of the discovery, of the nature and condition of the skeleton, and of the enveloping deposit. He confidently excluded all forms of intrusion and of burial by creeping or sliding, attested fully the true fossil nature of the remains, and referred them to that stage of the postglacial period when the Missouri river was running forty or fifty feet higher than now.

Previous to this there had been references to the discovery in the press, which had attracted the attention of Mr. M. C. Long, curator of the museum of Kansas City, who visited the locality, secured as many of the bones as practicable, brought the matter to the attention of neighboring scientists, and through them to the scientific world.

In *Science* of August 29, under the title, "Man in Kansas During the Iowan Stage of the Glacial Period," Mr. Warren Upham gave a brief statement of his observations and conclusions based on a visit to the locality on August 9, in company with Professors Winchell, Williston, Haworth, Mr. Long and others. Mr. Upham regarded the overlying deposit as loess of the Iowan age, and concluded that the skeleton had been "entombed at the beginning of the loess deposition, which would refer it to the Iowan stage of the glacial period, long after the ice sheet had receded from Missouri and Kansas, but while it still enveloped northern Iowa and nearly all of Wisconsin and Minnesota."

In the *American Geologist* for September, he presented the subject with greater fullness under the title, "Man in the Ice Age at Lansing, Kansas, and Little Falls, Minnesota." As before, the inhumation was referred to the Iowan stage of glaciation,

comparison was made with other human relics regarded as dating from the glacial period, and estimates in years of the duration of the several glacial stages were added.

In the same number of the *American Geologist*, Professor Winchell commented at length editorially upon the Lansing skeleton. He referred with implied approval to the article of Mr. Upham,

FIG. 1.—Side view of skull and femur found in the tunnel. From a photograph furnished by Mr. M. C. Long.

supplied additional information relative to the history of the discovery, to the deposit embracing the relics, and to the nature and condition of these. He regarded the main material penetrated by the tunnel as common loess, and located the skeleton in the unstratified limestone débris that lies below it. "It is hence preloessian, but probably not much older that the loess." He discussed at some length the age and relations of the loess, and concluded: "It will require, therefore, considerable further and careful examination of the loess sheets of Iowa, and of their relations to the till-sheets, as well as the marginal features of the till-sheets themselves, to enable any one to fix with any certainty

the age of the Lansing skeleton more exactly than is above indicated. That it dates from glacial time, at some remote point in the complex history of that age, is about all that can be affirmed from the present state of knowledge of the drift deposits."

On September 20 the locality was visited by Professors Samuel Calvin, W. H. Holmes, Erasmus Haworth, R. D. Salisbury, W. C. Hoad, Dr. G. A. Dorsey, Messrs. M. C. Long, F. R. Feitshaus, Martin, R. T. Chamberlin, and the writer. This visit was made at the request of Dr. Haworth and other geologists. A second visit was made on October 26 at the request of Professor Holmes and Mr. Gerard Fowke to inspect the excavations which the latter had made under the direction of the former. Mr. Long, Mr. S. J. Hare, and Dr. Haworth joined in this inspection. The Messrs. Concannon tendered all necessary privileges, as well as aid and hospitality. The following discussion is based on the data collected in these visits.

PRELIMINARY CONSIDERATIONS.

While the development of the science of river action in most of its phases is one of the gratifying achievements of recent decades, it is still to be confessed that a certain few of its aspects are among the laggard features of our science, and, as it happens, these are the ones most critically involved in the interpretation of the Lansing remains. It may not be amiss, therefore, at the outset to consider academically these special phases of fluvial action so far as essential to the present discussion.

1. *Scour-and-fill.*—One of these scantily appreciated subjects is the great depth and important function of scour-and-fill in certain of our large rivers. In this action both erosive and depositional work proceed *simultaneously*. It is well recognized that erosion and deposition may take place simultaneously in the stream bed and upon the flood plain, but the great depths and wide extent to which certain river bottoms are scoured out and promptly refilled is not always realized, nor the quick and constant reversals of this action. This is true especially of powerful rivers that flow upon a deep bed of loose material, as is the case with most of the large rivers whose bottoms were built up by

glacio-fluvial deposits during the ice age. The great examples are the larger members of the upper Mississippian system, and pre-eminent among these, the Missouri river whose bottom deposit is mainly sand and silt of an unusually mobile type. The vain struggle of the United States engineers to restrain the destructive shiftings of this river within bounds amenable to navigation and to permanent improvement on its banks, has brought out data which amply illustrate this profound instability, but this can only be fully appreciated by a detailed study of the reports of the chief of engineers.[1] Mr. L. E. Cooley, in his report for 1879, (p. 1066), makes the following among many other pertinent statements:

"To understand the difficult nature of the problem presented here [Eastport bend, on the Missouri river much above Lansing, but where the conditions are not essentially different], it is necessary to consider that at high-water, the banks are under water to a depth of three or four feet, and the current velocity is as great as seven or eight miles an hour. The erosion of the banks for several years past has been at the rate of about 1,100 feet per annum. When this was stopped by our revetment, a tremendous scour was set up, carrying the bed of the river thirty or forty feet below its normal position; in fact, the scour undoubtedly extended to the solid rock underlying the valley." And again (*loc. cit.*, p. 1071), "In many of the borings which have been made here, indurated clay balls with vegetable matter covered with a coating of sand, along with a motley collection of gravel stones, are found within a short distance of permanent strata. A precisely similar collection containing gumbo balls in a soft state was dredged from sixty feet depth at the works. These balls are from cutting banks, and the proof is conclusive that since the river has been running in silt banks as at present, scour has occasionally, at least, reached permanent strata at seventy to ninety feet depth."

Mr. Concannon informed me that eleven years ago the

[1] Professor Todd has called attention to some of these remarkable facts in his bulletin on the "Moraines of Southeastern Dakota and their Attendant Deposits," *Bull. U. S. Geol. Survey*, No. 158, pp. 150, 151.

engineers found a depth of water of ninety feet in the Missouri at a point about a quarter of a mile from his house, in what was then the channel of the river, but which is now abandoned and filled so that water covers the spot only at the highest stages of the river. Until about eight years ago the course of the river lay near the mouth of the valley in question, but is now diverted to the opposite side of the bottoms.

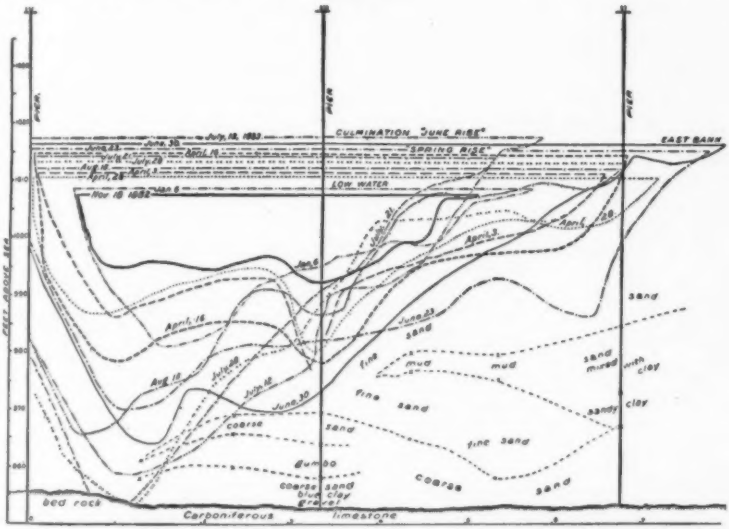


FIG. 2.—Diagram of the changes in the bottom of the Missouri river at Blair Bridge in 1883, as recorded by Engineer E. Gerber. Figure taken from Todd's *Bulletin United States Geological Survey*, No. 158, p. 151.

An accurate demonstration of the extent and rapidity of bottom changes is furnished by the accompanying diagrammatic record of the soundings at the Blair bridge, Nebraska, at the intervals indicated, in the year 1883, quoted by Todd on the authority of Mr. E. Gerber, assistant engineer F. E. & M. V. railroad.

An inspection of this will show that a skeleton might have been deposited on the surface of the Carboniferous rock bottom, much as in the case of the skeleton at Lansing, on the 28th of

July, 1883, and have been buried in alluvium as deeply as the Lansing skeleton by August 18, only twenty-one days later. Without doubt, within a few years it would be covered by sixty feet of alluvium through the migration of the channel of the river.

2. *The prevalence of this profound reworking.*— To illustrate how fully and effectually the whole of the bottoms of the Missouri river in this region are involved in its meanders and their shiftings, and how its bordering bluffs are being forced to retire by the impingement of the currents at its bends, a reduced copy of the United States Engineers' map is here introduced (Fig. 3), the section being about forty miles north of the locality in question, but representative of the conditions in all this portion of the river. It will be noted that practically the whole valley bottom is involved in the migrating loops, and that every part of its silt bed is liable to be disturbed again and again by scour and redeposit; indeed, it is probable that this has happened repeatedly to many portions, if not to most portions of the alluvial filling. It is perhaps not greatly beyond the facts to regard the whole bottom filling as being shifted, step by step down stream by successive scour and fill. This is more especially true of the borders of the bottom filling next the bluffs where the arrest and turn-about of the powerful stream gives the greatest rotatory and deep-disturbing effects.

3. *The absence of the great Dakota system of terraces.*—In the widening of the bottoms thus still in progress doubtless lies the reason why so few distinct remnants of the grand systems of glacial terraces and glacio-fluvial deposits of Dakota, described by Todd,[1] are found in this lower portion of the Missouri river. It is probable that the whole tract once occupied by these, and more besides, is now embraced by this widened, and still widening, zone of lateral encroachment. This is the less remarkable when we recall that the Missouri river was formed by the union of many preglacial streams of various connections whose lower courses were blocked up by the ice invasion so that they were

[1] *Loc. cit.*, pp. 128–140. The general nature of these is given in a later portion of the present paper.

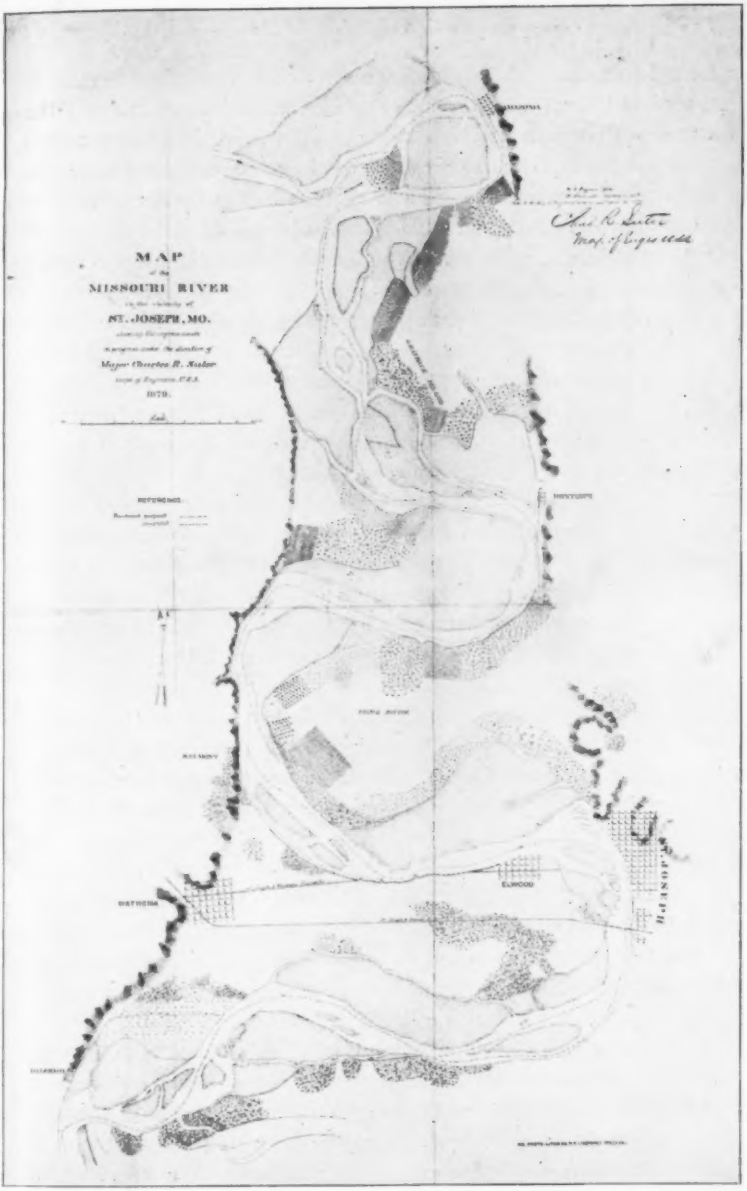


FIG. 3.—Reproduction of map of the Missouri bottoms at St. Joseph, Mo. From the *Annual Report of the Chief of Engineers for 1879*.

forced to unite and flow along the ice border. At first the newly assembled streams flowed either in the valleys of the smaller streams that entered into the combination, or in a new trench cut by the new stream across the cols between the united valleys. Thus at first it would not as a rule come into possession of a valley bottom of capacity adequate to the united floods, and in normal adjustment to them, and hence found little opportunity to make deposits. To the limited extent provided, its burden of glacial detritus was thrown down in these new and inadequate valleys, and as a natural consequence, it has been removed in the later process of working out an adequate valley and a suitable adjustment. The river is still engaged in making this adjustment.

4. *The significance of valley adjustment.*—If a great change is brought about in the drainage system of a region, such as the creation of the Missouri river by the junction of numerous antecedent rivers, and a new channel is developed to fit the new river, there at once arises the question whether the existing features of the valleys tributary to the new channel belong to the old or the new régime. In part they usually belong to both, and it becomes necessary to discriminate between these parts. This may be done by the study of their adjustments, a method especially applicable to small tributaries that have no permanent streams, as in the present case. The tributaries of the old system were adjusted to the old channel and cannot be presumed to be adjusted to the new channel, except in the rare case of exact coincidence of the old and the new channels. In relation to the new system, inherited tributaries usually present either the buried or the hanging type, or else they have become refashioned into adjustment to the new system. Such refashioning affects especially the mouths of tributaries. It often so happens therefore that refashioned configuration in conformity to the new system may dominate the mouth of a tributary, while its upper portions retain almost wholly the old configuration. These facts warn us of the danger of assigning great antiquity to fluvial deposits in the *immediate mouths* of tributary valleys if these valleys are *adjusted* to the present river or the present bottoms; especially is this true if the tributary is scarcely more than a ravine, and

its erosion and deposition are intimately conditioned by its relation to the river. In all such cases there is a strong presumption that the erosions and depositions at the mouth of such a tributary, such especially as have brought it into adjustment to the present and to the recent stages of the river, were contemporaneous with those stages and not accidental inheritances.

5. *Meandering as a cause of alternate erosion and deposition.*— A meandering river with a deep, readily-shifted, bottom-filling of the Missouri type imposes upon its tributary valleys alternate stages of excavation and filling. These result (1) from the action of the aggressive bends of the river loops against the mouths of the tributaries, and (2), the replacement of these, after a time, by the flood-plain peninsulas that lie within the loops. More specifically, it is the alternate cutting of the stream itself, working hard against and under the mouth of the tributary valley, followed by the building up of the river's higher flood-plain across the mouth of the valley. The first causes the waters of the adjusted tributary to erode; the second to make deposits in the mouth of the tributary; for in the first stage the axis of the tributary opens out on the river itself, which may be twenty or thirty feet, or more, lower than the upper flood-plain, and hence the tributary then has its lowest and best opportunity to discharge its waters and their detrital burden. Besides this, the river itself, while in this aggressive attitude, sweeps into the mouth of the tributary in its flood stages and aids in its excavation, and the rushing by of the river's strong current drags out by friction, on the principle of draught, the waters of the tributary, and, by acceleration, aids their excavating action. It is at this stage preeminently that the tributaries cut down their valleys into adjustment with the main stream bed. On the other hand, when the active impinging bend of the river has shifted elsewhere, and in its stead a flood-plain is being built up across the mouth of the tributary the drainage of the latter is checked, and if the tributary be small and its waters incompetent in comparison with the flood-plain aggradation of the river, the valley mouth will be filled to a height corresponding to that of the highest flood-plain. Now, the difference between low water and high water for the

Missouri river is given by Abbott as twenty feet at St. Joseph, above Lansing, and as thirty-five feet at its mouth; its extreme range is somewhat greater than this.

Further, if the mouth of the tributary be blocked by the upper flood-plain beyond the time of the latter's growth the wash from the tributary will build a delta, or fan, upon it, and this further growth will continue until the waters from the tributary valley have built up a suitable gradient for themselves across the flood-plain to the river. This only holds good in valleys of incompetent drainage which cannot cut and maintain a trench for themselves. If the tributary valley has a large, competent stream it will maintain a channel-way across the flood-plain to the river, and less aggradation will result from the shifting of the meanders, but that is not the case in hand.

If excuse for this academic statement is needed it is found in its special application to the case in hand; for either action of the kind just set forth is to be accepted as an elucidation of the case, as in the preferred interpretation that follows, or it is to be shown incompetent for such elucidation before we permit ourselves to go back of this action to earlier agencies. It is a vital principle of good practice that the agencies and phenomena nearest at hand be first considered, and, if the case requires, be eliminated, before recourse is had to more remote agencies. This is peculiarly true when, as in this case, the agencies closest at hand in time have quite certainly swept away the most of a more ancient record in making their own.

THE SPECIAL CASE.

The topographic environment of the relic-bearing deposit.—The site of the human remains is at the bottom of a small, short, rather steep-sided valley opening out on the flood-plain of the Missouri river. More specifically, the valley is less than a mile long, and less than half a mile wide, measured from crest to crest, and is about 160 feet deep at its mouth. The slopes on either hand are rather steep and nearly meet at a rather sharp angle in the axis of the valley, except that this is modified by the channel or dry run which forms narrow bottoms and little bluffs near the mouth,

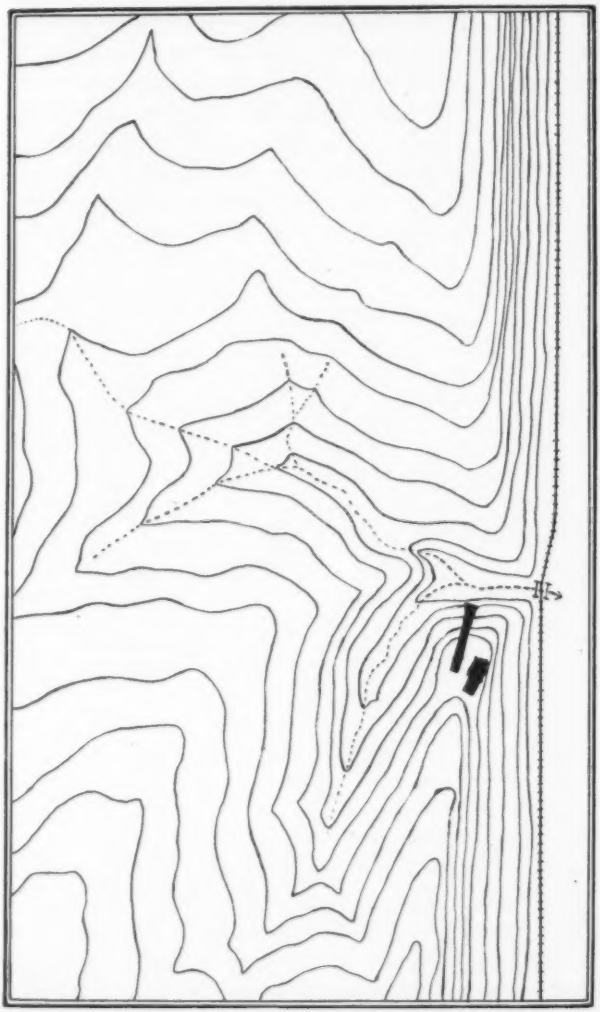


FIG. 4.—Topographic map of the tributary valley at Concannon's. From a sketch by Professor W. H. Holmes.

for the valley is not occupied by a permanent stream. The slope on the southward side is about as steep on the average as can be profitably cultivated; that on the north side is steeper, so that while the upper slope is cultivated the lower slope is left to natural growth and is partially occupied by quarries. On this steeper portion there are some small, vague, bench-like lines of uncertain interpretation; quite likely they are structural features dependent on the alternation of the more and the less resistant layers of the underlying strata. About twenty-five feet from the base of the slope there is an ill-defined bench that seems to be made up

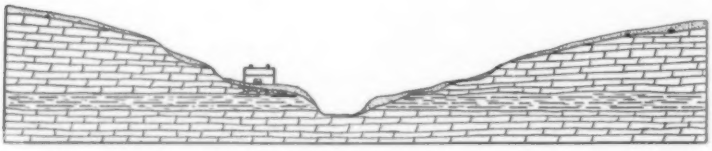


FIG. 5.—Section through the mouth of the tributary valley and the ridges on the north and south. Merely diagrammatic.

of lodgment matter adjusted to a former higher axis of the valley. There is a correspondingly vague bench on the opposite side. The ridges are composed of Carboniferous limestone, mantled by Pleistocene deposits (Fig. 5). The glacial drift is represented by some bowlders and smaller rubbish, but it is so scant and patchy as to be negligible as an element of the topography. The upland surface is mantled with loess and loam, the main portion of which is probably referable to the Iowan stage. The lower slopes are covered by wash from the uplands and by the skeleton-enclosing deposit which lies near the axis of the tributary valley and constitutes the vague benches above mentioned.

The back country is strongly rolling, the valleys fairly sharp, and their debouchures into the Missouri bottoms abrupt but well adjusted, and in their adjustments they represent the several normal types as well as several different stages. The bottoms of the Missouri are sharply defined by bluff faces. This is particularly so where the little valley in question joins it. The Missouri here runs southeastward, and the ridges bounding

the tributary valley on either side have been abruptly truncated by the waters of the Missouri and present a sharp talus face toward the bottoms. The recency of this face is a declared feature and is significant. Where not occupied by rock, the slope is formed of talus marked by slides and slump terraces so new as still to preserve their distinctive features. A very persistent slide terrace runs along the base of the south ridge at

FIG. 6.—View looking northward across the mouth of the tributary valley, showing Concannon's house at the left, and the truncated slope under it, the mouth of the valley just beyond, and in the center the north bluff with its truncated face overlooking the Missouri bottoms, on the edge of which the railroad lies. The bluff is about 160 feet high.

about the horizon of the skeleton's burial, ending nearly opposite it, and about ten rods distant. It is not intended here to suggest an immediate connection between this slide action and the burial of the relics, but merely to show the recency of the Missouri's work across the mouth of the tributary valley and within a few rods of the critical locality. This propinquity is brought into greater emphasis by noting that if a line be drawn from the crest of the talus slope of the north bluff to the crest

of the talus slope of the south bluff, it will run back of the skeleton's site. The significance of this close relation lies in the alternate depositional and aggradational work presumably done by the Missouri river at and in the mouth of the valley when it was truncating the adjacent bluffs on the one hand, and forming the adjacent bottoms on the other, in accordance with the principles of action outlined above. The accompanying contour map and photographs (Figs. 4 and 6–11), with their explanations, make these relations more definite.

The precise locality of the relics is more closely defined by an additional feature. A deep ravine starts near the crest of the ridge bounding the tributary valley on the south, and running nearly parallel with the truncated face overlooking the Missouri bottoms, joins the axis of the valley a few rods west of Concannon's house (see Fig. 7). East of this ravine there was doubtless once a round-back ridge of the usual erosion type with another ravine still to the eastward, but the encroachment of the Missouri has cut away the eastern half and substituted a steep talus slope. There now remains a sharp-edged spur descending toward the axis of the tributary valley, with a talus face on the side next the Missouri bottom, and a more gentle, yet rather steep slope to the ravine on the other side. Following down this sharp-edged spur, it is found to flatten somewhat for a few rods at about sixty feet above the bottom of the valley, much as though the flattened portion might be a remnant of a small terrace, structural or otherwise. Farther on, this breaks down, with rock exposure, for about ten feet to another flattening for another few rods. On this lower shoulder Mr. Concannon's house stands, beyond which the spur ends in a sharp descent of about thirty feet to the dry run of the valley. On the west side of the house the surface descends more gently to the ravine above described. It is under this westward slope, about one hundred feet back from the edge of the talus slope facing the Missouri bottoms, and about seventy feet southward from the little bluff facing the dry run of the valley, that the human remains were found buried about twenty feet deep. These details are given with some tediousness because they bear

upon the interpretation of the time and mode of deposition of the formation embracing the relics.

As already stated, the tributary valley is not occupied by a constant stream, but by periodic run-off. The channel at present is in a slightly aggraded and apparently still aggrading stage. It opens out upon the Missouri bottoms about two hundred feet

FIG. 7.—View of Concannon's house and environment seen from the south-southwest. In the foreground and center is the ravine leading down from the south, described in the text. The locality of the skeleton is nearly under the small white spot near the dark clump of trees on the slope at the left of the house. The ravine joins the tributary valley just at the left of this and the latter joins the Missouri bottoms in front of the house. The Missouri bottoms stretch across the upper part of the view, with the river (in its new course) and the opposite bluff in the extreme background.

from the locality of the relics, with perfect adjustment, and its recent deposits were slightly fanned out upon the bottoms of the main valley on our first visit, but had been largely washed onward by the rain that intervened before the second visit, illustrating the nature of the present adjustment. The depth of the

aggradation deposit is unknown to me, but it is probably not many feet, as the aggradation stage has but recently been inaugurated by the detour of the river. On the north side the spur next the Missouri bottoms grades down to this lower grada-

FIG. 8.—View from near the mouth of the tunnel looking northeastward across the bottom of the tributary valley, showing the gradation of the footslope of the north bluff into the Missouri bottoms seen at the right.

tion plain and the combination of lower slope and present bottom deposits is similar to that of an earlier date on the south side which contains the human bones (Fig. 8.)

The present aggrading washes have made a little bottom in the lower twenty rods of the valley, with meanders and little

bluffs where the loops bear against the older deposits of the valley. It is in the face of the little bluff on the south side, and about four feet above the valley bottom, that the mouth of the tunnel that disclosed the human remains is located. The base of the tunnel at its mouth is ten or twelve feet above the

Fig. 9.—View in the mouth of the tributary valley looking out upon the Missouri bottoms and showing the entrance to the tunnel at the extreme right. The material from the tunnel modifies the natural bottom, as seen in the foreground.

adjacent Missouri bottoms (Fig. 9). The lower four feet of the little bluff is formed of a thick bed of Carboniferous limestone; above this there is shale. The tunnel was started just above this limestone and driven back on its gently rising surface. It was carried by the Concannons seventy-two feet back from the face

of the bluff, and at its inner end its base is twenty-one feet five inches below the surface, an air-shaft permitting a tape-line measurement.

The relics found in excavating the tunnel represent an adult who had lost several teeth and a child whose teething stage, according to Professor Williston, implies an age of about nine

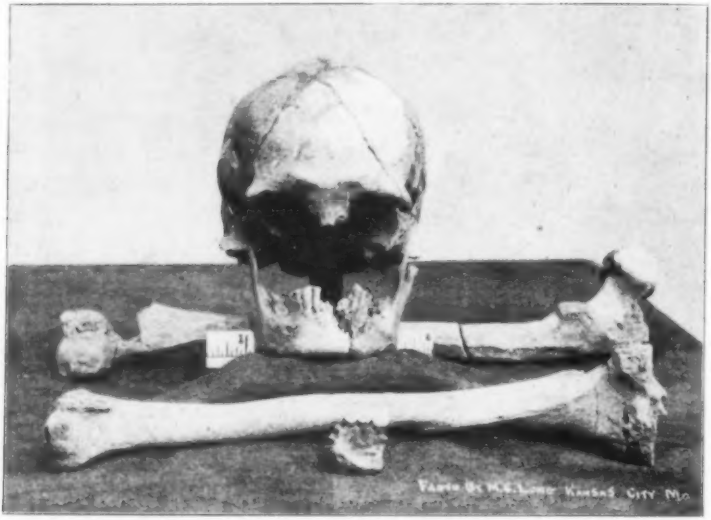


FIG. 10.—Front view of the skeleton of the adult and two of the associated bones, with the fragment of the child's jaw in the foreground. From a photograph furnished by Mr. M. C. Long.

years. The former is represented by a skull, femur, and other bones; the latter only by a fragment of a jaw (Fig. 10.) The bones of the adult are said to have been found near the inner end of the tunnel, and between one and two feet above its base. They were disarranged and at slightly different depths, but it is sufficient for present purposes to locate them at seventy feet from the entrance and twenty feet from the surface. The fragment of the child's jaw was found about sixty feet from the entrance and within a foot of the bottom of the tunnel. These statements relative to the discovery of the bones rest upon the testi-

mony of Michael T. and Joseph F. Concannon, who dug the tunnel. There is no ground to question their authenticity.

The associated deposit.—At the mouth of the tunnel the lower three or four feet of the deposit is composed mainly of limestone fragments and earthy débris, a part of the latter seeming to come from the Carboniferous beds, a part from the glacial drift or the loess, and a part from the river and valley wash; in short, a rather heterogeneous mixture. Some parts are highly oxidized and iron-stained and some parts are relatively fresh and calcareous. At about three feet above the floor on the western side there is a definite layer of dark, highly calcareous clay less than three inches thick, but it does not appear on the opposite side. It is thinner in the inner portion of the tunnel, where the cross cut of Mr. Fowke shows that it rises on the west side and pinches out irregularly within a few feet. The upper part of the deposit at the entrance is a mottled silt of loess-loam aspect, containing occasional stony fragments. Its response to acid is irregular, sometimes giving no obvious effervescence, sometimes a feeble action, and sometimes a prompt and marked response. Sometimes the action is concentrated in definite spots, as though it came from a bit of limestone. The action is not that characteristic of typical loess. Even in the top of the tunnel some limestone fragments were seen seven or eight feet from its base. Even in the inner end of the tunnel the silt is notably mottled, in part irregularly, and in part in bands, more or less horizontal, as though controlled by stratification, though the staining is probably secondary. Acid tests indicated that calcareous matter is present, but that it is not abundant.

These observations were made on the tunnel as seen on our first visit. Under the direction of Professor Holmes, Mr. Gerard Fowke later made a series of supplementary excavations in different directions to develop the formation further and secure additional fossils. A full statement of the results will doubtless be given in Professor Holmes's report. He has kindly permitted me to use such of the data thus gathered as are serviceable in the geologic determinations. Without entering upon precise details, it will suffice here to say that the tunnel was extended

southward until the rising of the Carboniferous beds in the bottom made further extension in that direction unpromising. Only a few feet beyond the end of the original tunnel Carboniferous shale was found overlying the heavy stratum of limestone, and the surface of this rose as though the foot slope of the ridge had been reached. The correctness of this inference is scarcely open to question as the whole environment supports it so strongly that it had been anticipated. The ease with which this shale was eroded, compared with the underlying limestone, readily explains the flat limestone surface on which the tunnel was run.

In an excavation on the west side of the tunnel, a shallow trench was found in the upper surface of the limestone running nearly parallel with the tunnel and also parallel to the axis of the adjacent ravine. With little doubt this trench was the axis of the ravine in the erosion stage just preceding the filling up of the ravine by the relic-bearing deposit. This further aids in explaining the nearly horizontal, but slightly rising, base of the tunnel, since it locates it alongside the axis of the ravine on a resistant bed (see Fig. 13.)

An offset tunnel at right angles to the original tunnel was run eastward eleven feet from the place of the adult skeleton. It developed about four feet of disturbed shale and mixed débris in its base, the vague structure lines of which dipped eastward irregularly. It had the appearance of a talus slump that had crept down the slope of the adjacent rock surface, and warped and slightly tilted itself backwards according to a common habit of such masses. This doubtless took place before the upper deposit was laid upon it and while yet the ravine was open, *i. e.*, about the close of the erosion stage. In the east end of this offset, the silty formation has been slightly fissured along a nomber of lines by tensional action and the little crevices filled with a grayish-white soft deposit that effervesced very promptly with acid, implying calcium carbonate. The riveing tension probably came from the tendency of the mass to creep on the underlying rock surface, since this rises to the east and so furnishes a sloping base of shale which arrests the waters descending through

the more porous mass above and which, thus becoming wet, presents an unctuous slippery surface favorable to creep.

On the west side of the tunnel the excavation was carried from near the point where the fragment of the child's jaw was found westward at right angles and was met by an open cut from

FIG. 11.—View from the westward showing the trench dug by Mr. Fowke from the ravine toward the tunnel with which it connects below. The original tunnel runs from left to right under the two trees seen beyond the end of the cut. The child's jaw was found at the intersection of the cut (extended by tunnel below) with the original tunnel just at the left of the trees. The adult skeleton was found nearly under the second light spot to the right of the two trees.

the ravine. This open trench (Figs. 11 and 12) afforded an admirable opportunity to study the constitution and structure of the whole section from the rock floor to the surface through a depth of about twenty feet. The definite clayey band found near the base in the tunnel is here wanting. As noted above, it pinches

FIG. 12.—Nearer view of the open cut shown in Fig. 11. The shadow obscures the larger portion, but the lighted portion on the left shows the absence of definite stratification, and indicates something of the mottled character of the deposit.

out irregularly a short distance west of the original tunnel. Putting all the facts together, it would seem that this little stratum was laid down in the axis of the ravine shortly after the stage of aggradation began. As it scarcely reaches three inches in depth at its thickest point—averaging probably less than an inch—and is very homogeneous and peculiar, as well as very fresh and calcareous, it was probably formed at a single stage of inundation. Aside from this there is no distinct stratification or lamination in the whole section, nor any complete assortment of the material. The main material is a silt somewhat closely resembling loess, but unlike it in the particulars already pointed out. Through this silt, at all heights from the base to the surface, there are dispersed fragments of limestone, shale, and other débris incompatible with a typical loess deposit. The limestone fragments were sometimes several inches across. Mr. Fowke, who gave careful attention to the distribution of this material, affirms that it was found indifferently at all heights, and I carefully verified this by an examination of the walls of the deep open cut. Small fragments of softened limestone were so abundant in some parts that the walls were mottled with the white chalky spots made by the spade in mashing and spreading them. There were also many bits of shale ranging up to an inch in length, not a few of which had been sufficiently weathered to be yellowish or brownish. These also occurred high up as well as low down in the section.

I have said that there was no distinct stratification, lamination or assortment in the section. There was some aggregation of the silt and the fragmental material. There were spots where the shaly and limy débris was sufficiently abundant to lend a gravelly aspect to the mass, but close inspection showed that it was not really assorted, laminated, or stratified. The agency of accumulation had obviously brought relatively more fragmental débris to these portions, or at least had left relatively more fragmental débris in these portions, than in average portions, but the aggregation did not rise to the grade of typical assortment and lamination. That it is a wash product seems to me clear, but not a stream deposit nor a lake deposit, nor any other form of

purely subaqueous deposition. I should identify it as a typical aggradation deposit of the ravine and basal-slope type where the hillside environment was Carboniferous limestone and shale mantled with loess.

A few pebbles of drift and not a few pieces of charcoal were found in the section, the latter at different horizons. Many land shells and some additional bones were also found by Mr. Fowke, but no unios. These interesting features will doubtless be described in Professor Holmes's report.

As had been anticipated, the excavations show that the extent of the deposit is limited, and that it was penetrated by

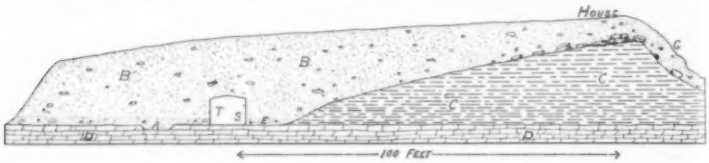


FIG. 13.—Cross-section from ravine at the left to truncated face overlooking the Missouri bottoms (*G*) on the right. The section passes through the end of the original tunnel (*T*) at the place of the adult skeleton (*S*). It shows the supposed original trench of the ravine in the surface of the limestone (*A*), the shale overlying the limestone, developed in the cistern and in the extension of the tunnel (*C*), the limestone blocks of the upper limestone under the house, and the deposit overlying the relics (*B*). The line marked 100 feet represents the distance from the place of the skeleton to the point where the truncated slope begins, not the whole length of the section.

the tunnel nearly or quite at its greatest depth. Rock comes to the surface just back of the house, and in the excavation for the rear end of the house, Mr. Concannon informed me that he reached rock which he thought was of the regular quarry kind. In sinking for a cistern eighteen feet deep on the east side of the house, he went through about four feet of dirt, then about two feet of loose limestone blocks, and then about twelve feet of "soapstone," so hard that he had to blast it. This is undoubtedly the Carboniferous shale encountered by Mr. Fowke in the extension of the tunnel. This makes it clear that the spur on which the house stands is formed mainly of Carboniferous beds and is merely mantled with the silt and débris formations. The accompanying cross-section is drawn approximately to a true

scale (Fig. 13) and shows the probable limitations of the deposit. The extension of the tunnel shows that it thins to the southward, while the ravine intercepts it on the west.

The surface configuration is that of a combined basal-slope and ravine-bottom deposit, *i. e.*, of aggradation in the bottom of the ravine, combined with deposits lodged on the lower slopes in adjustment to the aggraded bottom. The structure of the deposit is in keeping with this interpretation. The little layer of calcareous clay in the tunnel seems to imply deposition in standing, or slowly moving water, *i. e.*, a valley-bottom deposit, probably a back-water deposit. The absence otherwise of definite stratification or assortment of the material, and its complete resemblance to secondary slope accumulations derived jointly from the loess and the underlying beds seems to require its reference to aggradational action. Professor Williston found the cast of a clam shell with attached valves in the angle between the wall and the roof of the tunnel about seven feet from the base. In the absence of satisfactory evidences of fluvial action at this height and in the presence of human relics, this may well be referred to human agency.

INTERPRETATIONS.

The case is perhaps not an absolutely declared one, and a wholly unreserved interpretation may not be warranted, but a very strong balance of evidence seems to point in a specific direction. Certain things seem to me clear:

1. The deposit is not true original loess. It is a mixture of loess-like silt, Carboniferous detritus, water-laid clay and other débris. The Carboniferous detritus was obviously derived from the adjacent strata, in part by disintegration, in part by wear, and in part by fracture without much rounding. The loess-like silt was probably derived in the main by wash from the loess mantle of the adjacent hills, but in part also by winds from the Missouri bottoms; possibly also in part by creep. Its character implies that some of the silt was brought to its present position without complete leaching, while most portions show evidences of exposure and weathering. From such differences

of history probably arose the variations in color, texture and effervescence in response to acid, which were observed. The material of the one distinctly water-laid layer was probably derived from the Carboniferous shales at some special stage of erosion and inundation — some unusual storm and flood, perhaps — and was deposited without weathering, and remained undisturbed except on its borders.

2. The truncated faces of the adjacent Missouri bluffs, and the numerous slides on these faces, show that the Missouri river has worked extensively and effectively across the mouth of the tributary only a few rods from the site of the relics, and that this has been comparatively recent.

The rather steep slopes of the tributary valley favor the view that the *present fashioning* of these is recent. The main excavation of the valley probably dates back to the post-Kansan erosion interval, and this was perhaps preceded, and perhaps determined, by a preglacial valley. But the valley, *as it is now fashioned*, is pretty closely adjusted to the Missouri river bottoms which are features of recent origin, and *this adjustment and the slopes and deposits involved in it* is, by rather strong presumption, to be connected with the development of the adjacent Missouri channel. The age of the original valley and of the upland mantles does not concern us here, unless these lower deposits, well down in the axis of the valley, and at its junction with the great river bottoms, are surely inheritances from the older period, and not adjustment phenomena.

3. The record of these earlier events is here very imperfect. Even the record of the more recent of the Pleistocene events is very scant where it should be abundant and decisive if the conditions of preservation had been favorable. In Dakota, where the Missouri river came into relation with the last stages of general glaciation within its basin, there are three great systems of terraces as worked out by Todd,[1] viz.: 1) "The higher bowldery terraces," varying from 500 feet to 350 feet above the Missouri and connected with the outer moraine of the Wisconsin stage; 2) "The lower bowldery terraces," varying from 350 feet to

[1] TODD, *Bull. U. S. Geol. Surv.*, No. 158, pp 128–154.

various lower levels at different points, and connected with the second moraine of the Wisconsin stage, and 3) a complex system of "silt terraces" ranging from 150 feet downward, three or four of these terraces often occurring at the same locality. These last have not been traced into physical continuity with any of the moraines, and doubtless represent in part the very latest stages of glaciation, and in larger part the postglacial stages ranging down to very recent times. A reference to Todd's descriptions will show that these are not mere strands or slender benches on the valley sides, but great platforms, sometimes a mile or two broad. Now all of these three systems, so magnificently developed in Dakota, should ideally be represented in some way at the Lansing locality, but we have only the obscure, sloping shoulders already described, and the little deposit containing the relics. There is no sign that these belong to the first or second of the Dakota series which are directly connected with the first and second stages of the Wisconsin glaciation. In Dakota these terraces are formed of very coarse material, which gives them the title "bowldery," and this implies strong currents fed by glacial débris. Normally, these high bowldery terraces should graduate down-stream into finer gravels, sands and silts, all bearing the distinctive marks of their glacio-fluvial origin. The relic-bearing deposit is not of this type, and is not overlain by this type. The most natural inference then is that the train of glacial gravels, sands and silts borne away by the Missouri waters from the ice edge in the more vigorous stages of Wisconsin glaciation was carried away from this part of the Missouri channel before the relic deposits were formed. This is the more to be supposed because the Missouri has here recently run hard against the highlands and truncated them, and the tributary valleys are steep and in this special case, short and rather sharp. Remnants of the true glacio-fluvial deposits in this portion of the Missouri river are rare, and an experienced Pleistocene geologist familiar with their habit would not expect to find them in the mouth of so narrow, steep-sided, and steep-bottomed a tributary as that at Concannon's. The probable reason for the scantiness of the glacio-fluvial record in this part

of the Missouri valley has been given in the preliminary considerations. If neither of the strong bowldery terraces of so late a stage of glaciation as the Wisconsin are represented at the site of the burial, there is but scant ground to assume that the earlier and much feebler and much more erosible glacio-fluvial deposits of the Iowan are preserved.

The natural conclusion is, therefore, that the little relic-bearing deposit in the valley at Concannon's belongs either to the same class as the silt terraces of Dakota, to which it bears a measure of resemblance, or to some later stage.

Specific views.—While, as before remarked, the case is perhaps not a wholly declared one, and an unqualified identification may not be entirely warranted, the range of tenable interpretation seems to me to lie within narrow limits.

1. *The most conservative and the most probable view.*—All the essential facts known to me seem to be explicable on the following lines which involve the minimum of action and of assumption, and which appeal only to the natural order of things. The first stage of essential action is assigned to a time when the channel of the Missouri river ran immediately past the mouth of the tributary valley and was higher than now to such an extent as to be in erosive adjustment with the tributary at the top of the rather heavy limestone layer which lies just below the tunnel. It has already been noted that where a strong stream like the Missouri passes hard by the mouth of such a tributary, two effective conditions of erosion are supplied. The tributary has a low point of discharge and hence a high gradient, and its detritus is immediately swept away by the great river. During this stage the rock surface under the relic-bearing deposit was developed by the removal of the shales above, and the lower slopes adjacent were measurably denuded because the conditions were favorable to erosion and the shales were easily cut away. After a stage of erosive adjustment of this kind, a change of relations was brought about by the diversion of the channel of the Missouri river to some other portion of the broad valley, attended by the substitution of a flood plain at the mouth of the tributary. As the vertical range of water is now twenty feet or more,

the building up of a normal upper flood plain that much above the preceding erosion plain may be assumed. This must have been accompanied by a filling up of the lower part of the tributary in like measure. More than this, if the diverted stream in its new course ran on the opposite side of the bottoms, two miles away, the tributary might have also built a fan on the surface of the flood plain, with proportional further aggradation within its mouth. Now this filling up of the axis of the valley to the amount indicated, changed the condition of the lower sides of the valley, and these became covered with lodgment deposits derived from the upper slopes and with silts blown up from the Missouri bottoms, an action still in effective operation. Such deposits are the normal result of an effort to establish a new set of gradients adjusted to a lifted axis. The deposit resulting from these combined agencies should be just such a mixed nondescript one as the actual case presents, viz., a little clear stratification in the lower part, some suggestion of stratification of an uncertain sort in the other portions, but no complete stratification or assortment; a general absence of declared structure, some limestone débris, some shale débris, a little drift, some loess wash, some soil wash, with land shells, some stream or back-water silt, with river shells—perhaps humanly introduced—and some wind silt; and hence, some portions unleached and others leached, with other variations from a typical unitarian deposit, such as true alluvium on the one hand, or typical loess on the other. It seems to me that the depth of the deposit is quite within the competency of this method, while its general configuration and aspect are in close accord with this interpretation. Under this view the burial of the human remains took place either during the latest phases the erosive process of the stage indicated, or in the early phase of the building of the flood plain. The antiquity of the burial is measured by the time occupied by the Missouri river in lowering its bottoms, two miles more or less in width, somewhere from fifteen to twenty-five feet, a very respectable antiquity, but much short of the close of the glacial invasion.

2. *Possible but not probable interpretations.*—As previously

indicated, the case is not so declared as to render a given interpretation wholly certain, and to absolutely exclude all others. While I think them quite improbable, other times and methods of burial may be entertained as within the bare limits of possibility.

1) As noted in the description, there are some small and obscure shoulders or terraces at different heights up to sixty feet above the upper flood plain of the Missouri river. It is not clear that the higher of these are anything but degradational inequalities of structural origin, but it may be worth while to recognize that these features may possibly be of fluvial origin, and may be genetically connected with the lower deposit containing the human relics, though there is no clear evidence of this. In this case the working level of the river must be placed at perhaps sixty feet above that of the present day, and its waters must be supposed to have invaded the mouth of the valley more extensively and deeply. The site of the relics is thus placed in the bottom of the ancient river, though not in its main channel. It was therefore, more or less subject to the scouring action of the river bottom, and to alternate deposition and removal, as set forth in the preliminary considerations. At any stage during such submersion, when the current of the river was directed against the mouth of the tributary, it would be theoretically possible for the pre-existing deposit to be scoured out and replaced in the manner so constantly illustrated by the present action of the river, and in connection with such removal and refilling, the relics could be introduced. This would place the time of their burial farther back, but probably not so far as even the latest stage of the last ice invasion.

The specific character of the deposit does not seem to me to lend support to this interpretation. It is not distinctly and specifically fluvial, as it might be expected to be if formed in the bottom of the river or in deep and constant water of any kind, It bears the aspect of a mixed combination product, such as postulated in the previous interpretation.

2) It may be held that the relics were buried in the early stages of the Wisconsin glaciation, when the Missouri river was

rising because of the filling of glacial wash poured into it at the north. In this case it would be assumed that the tributary valley had previously been fashioned as it is now, that with the filling up of the Missouri valley it also became filled in the lower part, involving the burial of the relics, and that with the lowering of the Missouri since the glacial period, it has been re-excavated to its present extent. In this case the filling should have combined the characters of a glacio-fluvial deposit and a back-water deposit. The actual deposit does not seem to me to be of this kind. The present adjustment of the tributary to the Missouri river must also, in this case, be regarded as an accident, however improbable.

3) It has been held by Upham and Winchell that the loess-like deposit covering the relics is a part of the sheet of loess that mantles the uplands of this region generally, and is referred to the Iowan stage of glaciation, and that the relics were buried in the early stages of this accumulation, or earlier. This view receives more apparent than real support from the partial resemblance of the upper part of the deposit to loess. As already stated, this does not seem to me to be true original loess, either of the upland or of the fluvial type, but a secondary deposit, in part, and only in part, derived from the loess. If so, its age is that of its derivation, not that of the parent loess. Very similar deposits seem to have been formed at all ages since the main loess epoch, and are being formed now, and apparently must continue to be formed as long as the general loess mantle remains the chief source of erosion and re-deposition, but these deposits generally betray their origin by their secondary characters, as in this case.

4) It is even possible to regard the limestone débris in which the skeleton was found as preglacial detritus, buried first by the Kansan drift, which was afterward eroded, and then by the loess-like deposit; but in the first place, the detritus is not of the distinctive residual surface type, since it is not thoroughly weathered and leached as such deposits usually are, and in the second place, the hypothesis assumes that the post-Kansan erosion was adjusted to the preglacial erosion with a degree of

nicety quite improbable, and in the third place, the view leaves very little erosion and deposition to be referred to the long, subsequent stages, and in the fourth place, it leaves the adjust, ment of the tributary to the Missouri a matter of accident, and two accidents of nice adjustment in one hypothesis are somewhat too many.

5) At the other extreme, it is perhaps possible to refer the burial to very modern action of the Missouri waters at a very exceptionally high stage, combined with deposition by the tributary, aided by slope wash and creep and wind work from the Missouri bottoms. This seems to me, however, to be pressing agencies to the limit of their possibilities rather than resting with their probabilities within the limits of their more habitual action.

Without holding it to be quite demonstrable, it seems to me that the weight of evidence is very strong in favor of the first and most conservative interpretation, which finds an apt and adequate explanation in the natural order of things.

In this connection, I beg to invite the attention of archæologists to the slight grounds for hope of finding really strong evidences of man's antiquity in the fluvial deposits of the glacial rivers, because of the liability of these deposits to deep overworking by scour-and-fill. On the Ohio, for example, the floods are today boring out deep holes in the river and shortly filling these again, only to bore and fill somewhere else. It would doubtless not be difficult to sow coins of this year's mint over the bottom of this river in such a way that a decade hence they would be buried a score or some scores of feet in gravel and sand; and what is more, this gravel and sand would be of the glacio-fluvial type, since it would be only the true glacio-fluvial material rearranged by stream action not unlike that which originally formed it. It would hence be stratified, and nearly or quite indistinguishable in small sections from the original. The same process has been in progress ever since the river began to erode the glacial filling. If its early meanders covered the whole of the original glacial flood plain, no part of it would be exempt from the suspicion of such overworking and natural intrusion.

It thus appears that even if the burying gravels were of glacial aspect, and the burial were a score or two score, or perhaps even three or four score feet deep, it would require careful circumspection to remove legitimate and necessary doubts arising from this source. This might be done in special cases on geologic grounds, and the nature of the human deposit might in other cases help to eliminate these sources of doubt, but special and strong evidence of this kind is required to make a good case.

So far as the glacial ages are concerned, evidence of man's presence should be sought rather in the interglacial than in the equivocal fluvial deposits. With careful identification and reasonable circumspection, all sources of doubt as to age could be removed from the intercalated deposits of the interglacial epochs, and as these carry the relics of other life, they are competent to carry those of man if he really lived in the region at the time.

I am permitted to add the following notes by Professor Calvin and Professor Salisbury, who examined the deposit with me, and who have been kind enough to read and criticise my manuscript, as prepared before my second visit. The observations of that visit strengthened the grounds on which they have indicated slight divergencies from my views.

T. C. CHAMBERLIN.

STATEMENT OF PROFESSOR CALVIN.

I thank you for the opportunity you have given me to read the manuscript of your paper on "The Geologic Relations of the Human Relics of Lansing, Kan." I wish to thank you further, not for myself alone, but on behalf of all geologists engaged in the study of problems similar to the one under discussion, for the full and clear presentation of the behavior of rivers of the Missouri type in connection with migrations of their meanders, of their work in degradation and aggradation, in scour-and-fill, while deepening and widening their valleys, and of the changing conditions which they impose on their tributaries. The application of the principles discussed in the preliminary part

of the paper to the interpretation of the deposit in which the human bones were found near Lansing, Kan., as given in your Interpretation 1, seems to fit the case and harmonize all the facts in a very admirable way. If I were to dissent at all from your conclusions as stated in Interpretation 1, it would simply be to the extent of saying that a lowering of the Missouri valley since the bones and associated silts were deposited, through a space somewhat less than fifteen or twenty-five feet, would probably be amply sufficient.

SAMUEL CALVIN.

STATEMENT OF PROFESSOR SALISBURY.

With the general conclusion of the above paper as expressed under the heading, "The most conservative and the most probable view," I am in perfect accord. If I have any suggestions to add, they are the following:

1. Aside from the distinct layer of clay in one wall of the tunnel, I saw no structure which could properly be called stratification.

2. The band of water-laid clay seemed to me to imply stagnant or essentially stagnant water. I am disposed to refer its origin to a time when high water in the Missouri ponded the tributary. Since the level of the clay is but a few feet above the historic high-water mark of the river, the stream need not have been flowing more than a few feet above its present level when the clay was deposited. I see no reason for supposing that the introduction of the skeleton and the deposition of the clay were far separated in time.

3. The unequivocal layer of water-laid clay seems to me strong evidence against the view that the material in which it occurs is referable to any of the recognized loess epochs. I have seen thousands of sections of loess, but never one with such a seam of clay.

4. I regard the presence of the unio shell as evidence that the loess in which the tunnel is dug is not in its original posi-

tion. I am not aware that a unio shell has ever been found in undisturbed loess. The presence of the shell in *loess talus* — for that seems to me the proper characterization of the material in which the human relics were found — could be readily accounted for in various ways, one of which is suggested in the preceding pages.

ROLLIN D. SALISBURY.

STUDIES FOR STUDENTS

THE MAPPING OF THE CRYSTALLINE SCHISTS.

PART I.—METHODS.

INTRODUCTION.
Conventional geological maps a mixture of fact and theory in unknown proportions.
Outcrop maps needed to display the fact.
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Canons of mapping modified by basal assumptions.

INTRODUCTION.

CONVENTIONAL GEOLOGICAL MAPS A MIXTURE OF FACT AND THEORY IN UNKNOWN PROPORTIONS.—For areas of the crystalline schists no person save the maker or some one familiar with the area represented, can form any estimate of the value of a geological map. In proportions dependent not alone upon the worker and his conditions, but upon the area itself, theory has been compounded with fact, until the map represents not what is, but what the maker thinks after a study more or less extended. Unfortunate also it is that the thoroughness and detail of the study is not revealed. It is true that a geological map may be so constructed as to disclose at once an impossible condition, or one so contrary to common experience as to excite suspicion, so that von Decken, the greatest of German map makers, once said that there were really but two classes of geological maps—those that may be right and those that cannot be right. But on the other hand, a map may be prepared with but little examination upon the ground, which is quite as plausible in aspect, or it may be even more plausible, than one prepared by a conscientious and

competent worker who at great expense of labor and thought visits each exposure and studies it with respect to all its neighbors.

In regions in which rock types are easily distinguished, and where the tectonic structure is simple, the difficulties above referred to are reduced to a minimum; but in belts in which the rocks have been profoundly metamorphosed, and where orographic forces have brought about a complex structure, the dangers which arise from compounding fact and theory may be so great as to practically destroy the value of the map.

OUTCROP MAPS NEEDED TO DISPLAY THE FACT.— The largest element of danger is removed and a map increased very much in value by indicating upon the tinted areas of the different formations (the theory) the position, the nature and the observed peculiarities of the outcroppings (the fact). If a map has been made without sufficient field study this fact will then appear, and if it must be more thoroughly worked out and republished, the earlier work is not lost if it was intelligently and conscientiously done. If, however, it was carelessly, or for any reason inefficiently done, the examination of a few of the exposures which have been represented upon the map will supply the basis for judgment. In a complex area much time is consumed in making a just estimate of the value of a conventional geological map, and if revision is necessary the work must be taken up *de novo*, even if the field work was efficient so far as it was carried.

The serious objection to the general use of outcrop maps is, of course, the great expense which they involve because of the large scale which must be adopted. In the complex region bordering Lake Superior, the United States geological survey has most wisely adopted the plan of publishing outcrop maps to properly present the careful work of the geologists of the division. It is safe to say that the time is not far distant when equally precise methods must be adopted at least by government and state institutions for all regions of equal or of greater complexity.

FACT.—THE OBSERVATIONS.

ROUTINE FIELD OBSERVATIONS.—*Location of outcrops.*—The first requisite for geological mapping in a region of crystalline

rocks, is an accurate base map of sufficiently large scale. Unless the relief is slight or the topography of a simple character, it is essential that the topography be represented either by hachures or contours, preferably the latter. A scale of an inch to the mile (1:62,500) with a contour interval of twenty feet will no more than suffice to express the detail that is necessary for the best results. If roads are numerous and reasonably good, a bicycle with cyclometer attachment will be a valuable adjunct, and with little doubt the best way of securing base locations as well as getting quickly from place to place.[1]

By the use of the aneroid and 4-inch sighting compass, and by pacing, all locations can probably be made with sufficient accuracy if the base map is reasonably good and the country is one of diversified topography. In a wilderness like that about Lake Superior, where the monotonous uniformity of the topography and the forest cover make outlook impossible, the matter of location becomes exceedingly difficult. The problem has there been solved by scouring the country for outcrops in parallel and contiguous belts, a compassman accompanying each geologist to keep the direction and pace the distance, so as to allow him some freedom of movement.

Examination of rock and collection of specimens.—The examination of the rock is made upon the ground after securing the freshly broken surface of a specimen as little weathered as possible.

The specimen should be examined with the naked eye for its general aspect and compared with the weathered surface of the outcrop. Its manner of fracturing under the hammer may be of much significance, and of two closely similar rocks it may even remain the chief distinguishing difference in the field observation. With a pocket lens of a magnification of 6–14 diameters, according to personal preference,[2] a more careful examination is made of the fresh surface to note the essential and accessory minerals and their relative proportions, the texture

[1] HOBBS, "The Geologist Awheel," *Pop. Sci. Month.*, Vol. LVIII, pp. 515–518.

[2] The best lenses for the purpose are the Hastings aplanatic triplets, manufactured by Bausch & Lomb, Rochester, N. Y.

of the rock, the evidence of crushing, etc. A specimen of the fresh rock, in case the type is new to the region or of doubtful determination, is made by trimming a fragment into the shape of an elongated rectangular pillow three by four inches and of a maximum thickness of an inch. One or more chips for section cutting are also collected. When determinations are extremely difficult a series of smaller specimens untrimmed and showing the weathered as well as the fresh surfaces will be found far more valuable for identification and reference. These to the number of ten or more and representing as different phases as possible may be chipped from a single exposure or from near-lying exposures and given a single number as a series.

Measurement of strike and dip.—It is a time-honored and almost uniform practice to record the present direction of the plane of bedding in terms of the strike (the direction of the water line if the outcrop were partially submerged) and the dip (its inclination normal to the strike). Both these terms have a definite meaning when applied to the only slightly disturbed sedimentary rocks, and may properly be measured by the text-book methods, the former by leveling the compass with its north-south edge in contact with the bedding plane and reading the bearing, the latter by taking the steepest inclination of the beds—the one normal to the strike.

In the crystalline schist areas, however, the matter is far from simple. The rock may have no definite structure plane, either because of igneous origin or from metamorphism of a bedded rock. Again it may show one or more prominent structures, but no one of them may represent the plane of sedimentation. If one of them is proven to be the plane of bedding the best determination of the strike would probably not be obtained by the text-book method of placing the compass edge in contact with the rock surface. A quicker and generally more correct method is to hold the compass above or beside the exposure and adjust it by the eye to correspond to the average strike of the exposure. The error of the eye in adjusting to parallelism, which should hardly exceed 5°, is inconsiderable when the variation between different parts of an exposure or between near-lying exposures is taken into account.

Something further will be said upon the differentiation of original and secondary structures

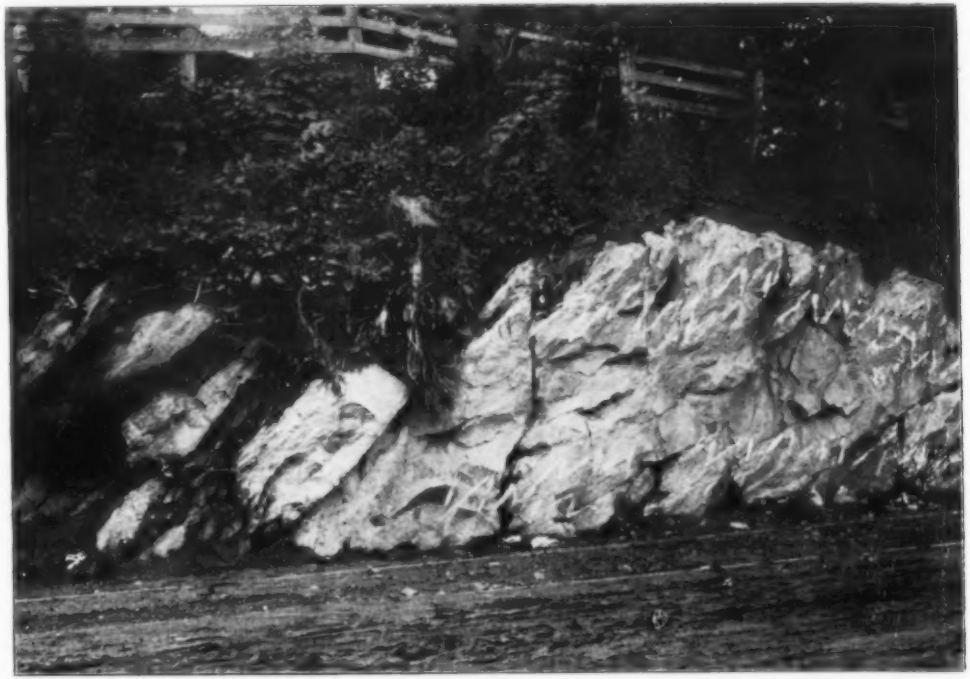
IMPORTANT ADDITIONAL OBSERVATIONS.— *Pitch and its measurement.*—Hardly less important than the inclination of the bedding plane at a locality is the pitch of the folds—the inclination of their trough and crest lines. Vital as is this element in the determination of the structure of an area, it is only in recent years that it has been given much weight in field investigations. It is safe to say that its importance is yet only half appreciated. To Professor Raphael Pumpelly, who directed the early field work in the New England area, is due the credit of bringing to the front this element in the field study of crystalline rocks. The details regarding the methods of measuring it were worked out by the assistants in his division.[1]

The pitch is often consciously or unconsciously measured as a component element of the dip, the dip being increasingly determined by the pitch as the outcrop is near the crest or the trough of a fold. Pitch can only be measured at the locality when the outcrop exhibits minor folds or plications, the study of the Green Mountains having clearly demonstrated the fact that the minor fold is the epitome of the major fold. The pitch is subject to the same kind of variations within an exposure as is the dip, and it must not be recorded from a single minor fold or plication without first noting whether other folds or plications give similar values. Even then its inclination cannot fairly be assumed beyond the exposure itself, and it is only by examination of a series of exposures that a *persistent pitch* is determined.

When not to be made out at an exposure, pitch (and here a persistent one) is correctly inferred when the strikes of the opposite limbs of a fold are other than parallel. A syncline pitches in the direction in which the strikes of its opposite limbs diverge and an anticline in the direction in which they converge.

Inferences regarding the pitch may often be drawn from the profiles of ridges, the gradually sloping lines being formed by the crests of folds.

[1] See *Monograph XXIII, U. S. Geol. Surv.*; also VAN HISE, "Principles of Pre-Cambrian Geology," *Sixteenth Ann. Report U. S. Geol. Surv.*, Part I, 1896, pp. 603–632.



SECONDARY FOLIATION AND BANDING IN GNEISS ON STATE ROAD NEAR GREAT BARRINGTON, MASS.

The direction of the original plane of bedding is now nearly horizontal as indicated by the lines of crumpled quartz lenses near the top and bottom of the exposure. The secondary foliation and banding appear at the left and between the crumpled rows of quartz lenses.

Van Hise has shown that the crests of folds are lines of special importance by reason of the fact that the order of superposition of beds is there almost sure to be the normal one, and the additional fact that crushing being there at a minimum, conglomeratic and other original structures are most likely to be preserved.

Form of minor folds.— As might be inferred from the last section, the form of the minor fold or the plication is full of meaning respecting the characteristics of the larger folds of the region, and it should, therefore, be carefully studied and its peculiarities sketched or recorded.

Secondary foliation and its relation to bedding.— Foliation is one of the commonest of the structures in the crystalline schists. It is now well known that in the recent past the strike and dip of foliation have rather generally been measured as those of bedding, so that in most papers, written more than a decade since, the secondary nature of foliation was not recognized, and recorded observations of dip and strike as frequently refer to secondary foliation as to planes of sedimentation. Even with the larger knowledge of the present, the differentiation of the two structures is difficult and often impossible. Two, three, or even more sets of planes of separation, with widely different directions, may all be easily made out in the same hand specimen of clastic rock, and yet no one of them correspond in direction with the bedding plane.

A difference in composition characterizing alternate parallel bands of considerable thickness is undoubtedly the best criterion for determining the plane of sedimentation.[1] A striking instance of secondary banding is represented in Plate I, where the bedding plane is outlined by the crumpled lenses of quartz and by even more beautiful puckered bandings not discernible in the view. The secondary straight banding is parallel to the foliation. (Plate XIV of the work last cited is from near this locality.) Such a structure, or one resembling it, may, however, be produced by the mashing of a coarse granite or conglomer-

[1] See, however, HOBBS, "Secondary Banding in Gneiss," *Bull. Geol. Soc. Am.*, Vol. III, pp. 460–464, Pl. XIV.

ate, but the characteristic structures of these rocks are usually not obliterated unless the bands are reduced to a thickness of a quarter of an inch or less. Again injection of granitic material along the planes of foliation of a rock may produce an alternation of bands of different composition. Such a structure is, however, apt to be recognized by an experienced observer, and unless subsequently mashed the bands are not sufficiently uniform in thickness to simulate bedding.

Of all the crystalline rock types of clastic origin, quartzite offers the greatest difficulties in the search for the bedding plane. In fact, it is generally impossible to determine it except by contacts with other formations.

Other things being equal, the more crenulated or wavy a structure, the greater the probability that it is original. Also the more its general direction diverges from an undisturbed plane of foliation the more likelihood is there that it is earlier and original. When the bedding plane cannot be made out with certainty at a particular locality it may sometimes be inferred from a study of the form of the minor folds in their relation to foliation at a neighboring locality. Owing to the fact that mashing is at a minimum in the arches of folds, careful search in an area of closely compressed folding will often reveal at regular intervals the beautifully crenulated arches with foliation planes bisecting them, although between such localities the foliation planes only can be found. Such a method may even be applied to a slate. The green and purple slates of the Taconic range of mountains dip to the eastward persistently and quite uniformly. The writer was able to find at fairly regular intervals across the strike of this foliation the acute crests of easterly dipping anticlines preserved in lenses of infiltrated silica, thus showing that a series of moderate thickness has, by buckling and compression, brought about perfect foliation parallel to the axial planes of the folds, and thus given the impression of vast thickness.

Van Hise, in his treatment of the mechanics of flexuring—confirmed by field observation—has shown that in moderately compressed folds the foliation planes of the opposite

limbs converge downward in an anticline and upward in a syncline.[1]

Joint planes.—Joint planes more or less perfectly developed are almost universally present in the crystalline rocks. They are planes of separation in parallel series, of which more than one is usually to be made out. They usually have a very steep inclination and are probably like the folding, in most cases a result of the compression of the area. Their number (*i. e.*, the number of series) and relative perfection, and the direction and inclination of their walls, should be carefully noted, with the relation of these to lines of displacement and to topographic features.

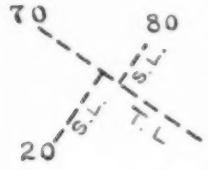
Scarps and steep rock walls.—Little attention seems to have been accorded these features of rock exposures. In the sequel I propose to show their importance in the geological structure of a region. Their direction and magnitude should be noted, and if possible some symbol easily distinguished from the dip and strike symbol should be entered at least upon the working map. A short dotted line will serve to indicate the direction of the scarps and a figure at its end its bearing to the east or west of north.

Margin of outcrop.—Another neglected feature of rock exposures is the margin of the outcropping. Every experienced geologist must be able to recall numerous instances where outcrops, grouped so thickly as to indicate probably but slight covering in the intervening area, cease abruptly at a border which is often nearly or quite rectilinear and perhaps is also for sections of its extension the margin of individual exposures. Such observations, it is believed, are of great significance in the proper interpretation of the structure of a region.

Gorges and sharp straight valleys.—Even the best of the topographical maps do not indicate all gorges or rectilinear valleys with rock walls. In the interpretation of the geological structure their significance may be considerable, and it is important to note their direction and in many cases also the height of their

[1] See on the general subject of foliation, PUMPELLY, WOLFF and DALE, *Monograph* XXIII; *U. S. Geol. Surv.*, pp. 136–158, Pt. I, 1896; and VAN HISE, *Sixteenth Ann. Report U. S. Geol. Surv.*, Pt. I, pp. 633–668.

walls. A symbol like the cut will be found useful in recording them upon the map. The figure at the end of the trough line of the valley indicates the bearing in degrees to the east or west of north, as the case may be. The slope lines on either side pointed toward the trough are like Dana's dip symbols adjusted in length to indicate the steepness of the slope, a large slope line indicating a gentler slope. The figures used in connection with these lines indicate the height in feet of the walls on either side, an estimate being expressed by the ± sign. Very large and important valleys are often omitted from topographic maps the topography of which is sketched, because hidden from points at which the sketches were taken.



Nature of contact surface of formations.—Contacts of formations wherever exposed should be carefully scrutinized, not only to discover evidence of conformity or unconformity, but for indication of slipping, thrusting or faulting. The contact plane of formations for two reasons is likely to be a locus of displacement. In the first place contacts are likely to be planes of weakness where a maximum of movement has occurred; and in the second place, displacement, whether by normal faulting or thrusting, produces new contacts. It is, therefore, to be noted at the contact of sedimentary formations: first, whether the plane of contact is the natural result of sedimentation, and whether conformable or not; second, whether the deformation of the contact plane, if present, is such as may be explained by accommodation of layers in flexuring, or must be accounted for by the more violent processes of normal faulting or thrust. With good exposures the direction of the plane of displacement will probably allow of a decision between thrusting and normal faulting. If insufficiently exposed the nature of the folding and the general character of the deformation within the area may afford a clue. Both normal faulting and thrusting may, however, have occurred at the same contact.

THEORY.—THE DRAWING OF BOUNDARIES AND COLORING OF MAP.

THE CANONS OF GEOLOGICAL MAPPING FOR THE CRYSTALLINE AREAS.—The determination of what types of rock shall be grouped under one formation-color may be a problem of the greatest difficulty, but in the absence of conglomerates or clearly marked unconformities, the question is a petrological one to be settled by the best judgment of the observer on the ground checked by subsequent microsopical and perhaps chemical investigation in the laboratory. Where the contacts are not sharp but exhibit gradational facies, there may be a question as to where the dividing surface should be fixed, but this is after all a matter of comparatively small moment, and however determined, there is little danger that much violence will be done the facts.

The drawing of boundaries where contacts are not exposed—and contacts are generally covered—is a problem calling not only for much judgment but often also for a large imagination. In most domains of science the worker is allowed to express his lack of adequate data upon which to base a conclusion, and to reserve his judgment pending the obtaining of fuller information. Here, however, the demand is peremptory and the line must be drawn with or without knowledge. It is no uncommon experience to find within a region of intricate geological structure an alluvial valley a mile or more in width bordered by drift mantles of only lesser width before the bed rock is exposed. However the boundary lines of the formations are drawn, the map maker may be reasonably sure of one fact only,—that the reality is totally different from the representation. Convention requires that all areas shall be colored to show the underlying rock, and it may at least be said that the result is every whit as attractive and plausible in appearance as though the coloring were based throughout upon observed facts.

It is perhaps a step in the right direction to leave the lakes and rivers uncolored, as is now done by the United States geological survey upon its atlas sheets; but to this also there are serious objections, as, for example, in the area about New York city, where the numerous bridges, piers and abutments, tun-

nels, and government dredgings afford a body of knowledge of the submarine bed rock equal to that obtainable from most land areas.

The necessity for drawing boundaries in covered areas has evolved a body of largely unwritten doctrine which may not inaptly be referred to as the canons of geological mapping for the crystalline areas. Some of these canons are truths, others half truths, and still others have little basis in fact. Some of the more important of them are subjoined with brief critical notes. They are of course to be weighed in connection with one another and a compromise decided upon.

1. *Propinquity of outcrop.— Near-lying outcrops should be connected when not separated by outcrops of a different formation.* This rule is almost axiomatic and thoroughly sound in principle provided no contrary evidence is at hand; but there is yet a possibility of error even when outcrops are separated by less than one hundred feet.

2. *Contacts covered.— The boundary is not at the margin of either of the separated outcrops of different formations, but at some line between.* This is a general rule but with many exceptions.

3. *Strike.—Direction of boundary conforms to strike of near outcrops.* A rule of much value but to be weighed with other considerations before decision is made.

4. *Slopes.— On slopes boundaries should be corrected for strike and dip.* With vertical beds if the strike is away from the elevation in the general direction in which the boundary is being extended, the boundary will run down the slope, if toward the elevation it will run up the slope. If the slope also changes in such manner that the contour line converges less or diverges more from the strike the boundary will curve more rapidly down the slope; if the contours diverge less from or converge more with the strike in that same direction, the boundaries will the more rapidly ascend the slope. If the dip is with the elevation the boundary bends the more up the slope, if out from the elevation the more down the slope.

5. *Topographic breaks.— Sudden changes in slope not caused by talus or drift are likely to correspond to contacts.*

6. *Variable hardness of rock.— Ridges are occupied by harder rock, valleys by softer or more soluble rock.* To be applied with great caution. In many districts, in the opinion of the writer, the valleys are nearly if not quite as often hard as soft rock. A structural line of weakness may have produced a pre-glacial stream bed which the ice-cap widened and deepened; an antecedent stream may have produced the same result in hard rocks, an orographic block may have suffered depression, etc.

7. *Hydrography.— In a limestone and hard rock country lakes, ponds, rivers, and swamps are generally in softer or more soluble rock.* A most pernicious doctrine because so generally accepted and so frequently wrong. Faith in the canon also discourages investigation. The writer has in mind a nearly circular lake in the middle of a great valley largely underlaid by limestone, but about one-half the lake bottom is mica schist, the other half limestone.

8. *Ridge and valley structure.— Ridges are more generally synclines and valleys anticlines.* A half truth. It is perhaps true in the greater number of instances of rocks which suffer an amount of plication and rupturing of flexures (schists, slates, and sometimes limestones). It is not true of the heavy gneisses which so generally raise their heads in domes, the beds quite generally dipping with the slopes.

9. *Blocks.— Angular blocks when not lying on steep slopes and not clearly ice borne are on bed rock of the same kind.* The tendency is to drive this doctrine to its limit. For great limestone blocks not strengthened by silica or silicates it may perhaps be assumed that they are not very far from the parent ledge. With a framework of silica they have been carried by the ice thirty miles or more.

10. *Sink-hole structure.— Superficially undrained areas when not morainal (or in drift) are on limestone.* A pretty safe rule.

11. *Soil.—In a limestone and hard rock country arable farm land is on limestone and woodland on hard rock.* A fairly useful rule if applied intelligently.

CANONS OF MAPPING MODIFIED BY BASAL ASSUMPTIONS.—The above canons are to be considered in connection with one

another, the worker giving to each what weight in his judgment is best to secure a compromise for the result. They are perhaps as good a set of rules as we can secure for the settlement of matters regarding which the known facts are insufficient to allow of a definitive conclusion.

A map constructed upon observations and rules as above outlined might be difficult to read, as the order of superposition of the formations might not at once be clear. The formations do not always appear upon the map in their direct order, being sometimes inverted, and sometimes individual formations do not lie next to their immediate neighbors above and below. The map maker is expected to show how each formation has been brought into its present positions and attitudes, to do which fundamental assumptions of far-reaching importance are made Theory is thereby brought in very large measure into the solution of the problem, it may be so as to take precedence over the canons of doctrine which have been outlined above. These basal assumptions and their effect upon the map will be considered in a second paper.

WILLIAM HERBERT HOBBS.

Editorial.

The discovery of human remains under twenty feet of débris near Lansing, Kan., has revived interest in the antiquity of man in America, and fortunately on more hopeful lines than heretofore, since the mode of occurrence at Lansing is more definitely determinate than in most previous cases of the kind, and the geologic elements of the problem are more declared, though, as it happens, they belong to a much overlooked yet very common type. The recent studies of Brower and Winchell on the quartz chips at Little Falls have brought that case into more definite form.

There remain about the same differences of interpretation as heretofore, but these will pass away as the specific identification of glacio-fluvial, alluvial, and sub-aërial adjustment deposits becomes more familiar and precise, and as their interpretation is at once given greater latitude and made more strictly dependent on discriminative criteria.

In the judgment of the writer, neither of the above cases affords any substantial ground for affirming the presence of man in America during the glacial period; but they do afford a strong presumption that man in this country has witnessed very notable progress in the deepening of the channels of the Missouri and Mississippi rivers. In time there may be found means for estimating the rate at which these rivers are lowering their channels, but at present these are wanting, and there is no trustworthy method of estimating in years the time consumed in the deepening which has taken place since the human relics were buried.

T. C. C.

Reviews

Kakabikansing. By J. V. Brower. St. Paul, Minn.: H. L. Collins & Co.

Under this bizarre title Mr. Brower has described the occurrence of quartz chippings at Little Falls, Minn., prefixing a sketch of the previous studies of Winchell, Babbitt, Upham, Hill, Holmes, and Hershey, and affixing a letter from Professor Winchell and a statement on "Primitive Man in the Ice Age" by Mr. Warren Upham. The descriptions of Mr. Brower are apparently careful and candid, so far as intention goes, but they are obviously not those of a critical geological observer. They neglect most of the really discriminative factors and embrace much inconsequential matter. Notably also they have the trait, so common to the untrained worker, of incorporating interpretation unconsciously while insisting on "ascertained facts." "The glacial river" plays a notable part in the description of the formations, whereas the very thing to be demonstrated is the "glacial" or non-glacial character of the river at the time the formations in question were made. None the less the excellent photographs and the maps, together with the statement of Professor Winchell, largely supply the lacking data and make it possible to consider whether the interpretations put upon them are the normal ones or not.

From these it appears that there overspreads the plain once occupied by the Mississippi waters, but now above their reach, a surface layer of dirty pebbly sand of the typical structureless kind which usually covers abandoned flood plains of sand and gravel. This is about four feet thick and at places near the river contains many chips of white vein quartz of undoubted human origin. The source of the quartz is unquestionably the veins in the outcropping slate over which the falls are formed. This quartz-bearing slate does not now rise as high as the upper surface of the plain, and this fact has been urged by Holmes and Hershey as evidence that the quartz chippings were not taken from the parent ledge until the plain had been cut down to the requisite depth after its original completion. Mr. Brower, while not answering this objection by positive evidence, holds that the crest of the quartz-bearing ledge was exposed at seasons of low water, though

covered at times of flood. It is of course probable that the crest of the ledge has been worn down where the river flows over it, but such erosive covering by the river does not fit in well with the view that this same portion was the source whence large quantities of vein quartz were quarried at the same time. It is clearly urging a bare possibility at best rather than a probable occurrence.

If, however, the case rested merely on the possibility of reaching the source of the quartz while yet the uppermost layers of the original plain were in the process of formation, it might be ungenerous to refuse to entertain the utmost possibilities of the case in favor of glacial man in America. But the facts of the case, taken just as given in this paper, do not seem to the reviewer to afford even a plausible ground for assigning the quartz chips to the glacial stage of the river. The surface deposit in which they are found, as described and illustrated in the paper, not only does not bear the characteristics of a glacio-fluvial deposit, but bears quite clear evidence that it is not glacio-fluvial. The descriptions cite the fact that the surface deposit is highest near the bank of the present bottoms, after the common habit of existing degrading rivers. This habit is recognized and the facts are summarized in the following quotation (p. 73): "At Little Falls, Minn., the eastern portion of the sandy plain on the east side of the Mississippi is several feet lower than the crest of the plain at the east end of the dam. That fact is important. After the great glacial river which overspread the entire plain at Little Falls had withdrawn into the narrower limits of an eroded streambed, that river, often in freshet from the effects of the melting ice-sheet, occasionally re-overflowed the entire plain, disturbing and overturning the sandy surface, mixing into its materials every chipped quartz blade or spall which had been placed by the hand of man upon the surface adjoining the newly eroded and narrower channel. The higher altitudes of the plain along the Mississippi between 'The Notch' and the dam were caused by successive stages of recurring overflowage, creating additional surface deposits upon the plain nearest to the newly formed river bank." This is indeed "important," as the author himself naïvely remarks, since it shows, as the author also recognizes with equal unconsciousness of its real meaning, that it is the characteristic action of streams of *the present non-glacial régime*. It is here recognized, with undoubted correctness, that the quartzes were buried "by disturbing and overturning the sandy surface" and by "additional surface deposits." The reference of this, however, to *glacial* waters is

wholly without evidence and quite against the probabilities. Glacial streams as a rule have the aggrading habit, and are not therefore "withdrawn into the narrower limits of an eroded streambed," but on the contrary, are constantly shifting their courses from one point to another across their whole plain. Usually they subdivide into a complex plexus of numerous shallow shifting branches. There is therefore no reason whatever to suppose that the present channel of the Mississippi at Little Falls was in existence, even in its initial stages, while the river remained truly a glacial stream. The fact that the relic-bearing deposit is closely related to the present stream is *evidence that it was postglacial.* The deposit that carries the relics supports the same view, for it bears the characteristics of a postglacial rather a glacial formation. On the evidence submitted, therefore, in the paper the inference is rather imperative that the quartz chips were buried at some stage when postglacial rather than glacial conditions prevailed. To make this more clear, it may be worth while to sketch the normal succession of events and to gather from these the normal interpretation of the time and mode of burial of the quartz chips, assuming, as everywhere throughout this review, the complete trustworthiness of the evidence given in the paper, especially that afforded by its excellent photographic illustrations.

1. During the time the glacial border lay across the sources of the Mississippi and it was therefore truly a glacial stream, the normal inference is that it had the aggrading habit because of its overburden of glacial detritus; that it took the form of a plexus of numerous branchlets, and that it occupied, by the constant shifting of these, the whole plain which it was engaged in building up. In the nature of the case it should normally have no fixed channel nor any permanent flood plain deposit, since its whole plain was periodically covered by the channels of the branching and shifting streams. Its typical deposits should have been clean, fresh, well-assorted stratified sands and gravels. Any human relics left anywhere on the plain, even on portions not at the time occupied by the stream, should have been worked over and incorporated more or less deeply by scour-and-fill in the clean, stratified gravels and sands. None such are reported.

2. When the glacier had retired from the basin and no longer overloaded the Mississippi with its detritus, a transition stage should naturally have followed. During this the first work was to adjust the stream to the conditions that immediately followed the glacial retreat. It is to be presumed that the upper branches of the river were aggraded

to different slopes, dependent on their relations to the glacial supply of detritus thrown into them. As a rule, the gradient is much higher near the ice edge than at a distance from it. These high gradients are presumably the first to be reduced, while the material so derived is shifted to the lower gradients which continue their aggradation until the whole becomes adjusted to the new conditions. It must also be considered whether the fresh drift surfaces left by the recent retreat of the ice and the numerous new trenches of the young streams engaged in developing the new drainage system may not have kept the Mississippi in an aggrading, or at least static condition for a notable period after the direct influence of the ice sheet was withdrawn. Any human relics left on the plain during this stage should normally have been subject to incorporation by scour-and-fill in the clean, fresh, stratified gravel. But none are reported.

3. After the stage of transition had passed and the Mississippi had assumed the degradational phase, a period must probably be recognized during which its shifting meanders occupied the whole of its plain — except occasional protected embayments — and degraded it from side to side, removing the whole surface of the previous glacio-fluvial and transitional-adjustment plain. This action is dependent on the balance of prevailing conditions, and these vary for different rivers and different portions of the same river. To a large extent, the Mississippi has continued action of this phase down to the present time and has cut away the whole of the upper part of the glacio-fluvial plain. It is only here and there in favored localities that any remnants that can with probability be regarded as portions of the upper glacio-fluvial plain can now be recognized at any great distance from the ice edge. Just how long the river would continue to occupy by its shifting courses the whole upper plain at Little Falls cannot be determined by any evidence given in the paper, but the stage should be recognized in the interpretation of the history of the region, and particularly in the determination of the age of the surface deposits of the plain as it now exists. Any human relics left on the plain in this stage would be liable to be incorporated in the clean stratified gravel by scour-and-fill. But none are reported.

4. After the stages above noted had passed, the river developed a more restricted track and limited its erosion essentially to this, sinking its channel gradually into the broad plain and covering the remainder only in flood time. It would continue to flood the upper plain until the channel reached a depth greater than the height of the flood stages.

What this height is habitually in this part of the Mississippi is not known to the reviewer. The range between low and high water is given by Abbott as twenty feet at St. Paul, thirty-five feet at the mouth of the Missouri, and fifty feet at some points below. From the data given in the paper, it would appear that in the natural river, before influenced by damming, the low water was from twenty to twenty-five feet below the main plain. If, therefore, an average flood stage were applicable to this locality, the deepening of the channel since the river floods rose to the plain could be estimated at only a few feet, but the barrier formed by the slate renders an estimate of the time very uncertain. If the slate were once much higher than now, it should have kept the river longer within reach of the plain at flood time, so that the hypothesis that the slate has been notably cut down by the river, introduced to avoid the criticisms of Holmes and Hershey, is not without its embarrassments in another direction.

Now, it seems clear from the evidence presented in the paper that the quartz chips were not spread over the plain while the clean stratified gravels were being formed, nor while the river was meandering over the plain in its transitional-adjustment stage, nor in its general degradational stage, for at all of these stages, scour-and-fill should have incorporated the chips in the stratified sands and gravels. The chips were quite clearly introduced after the Mississippi had "withdrawn into the narrower limits of an eroded stream bed" and while only its flood stages overflowed the upper plain. This normally occurred in the fourth stage sketched above. As the recent cutting down of the channel has been slow on account of the slate barrier, a very considerable period has probably elapsed since the Mississippi last reached the upper plain even in its highest flood stages, except as these might be made exceptional by ice jams and similar obstructions. This gives the origin of the chips a respectable antiquity, but does not offer any presumption that it fell within the glacial period, or even very near its close. This seems to the reviewer to be the normal interpretation of the evidence presented in the paper.

T. C. C.

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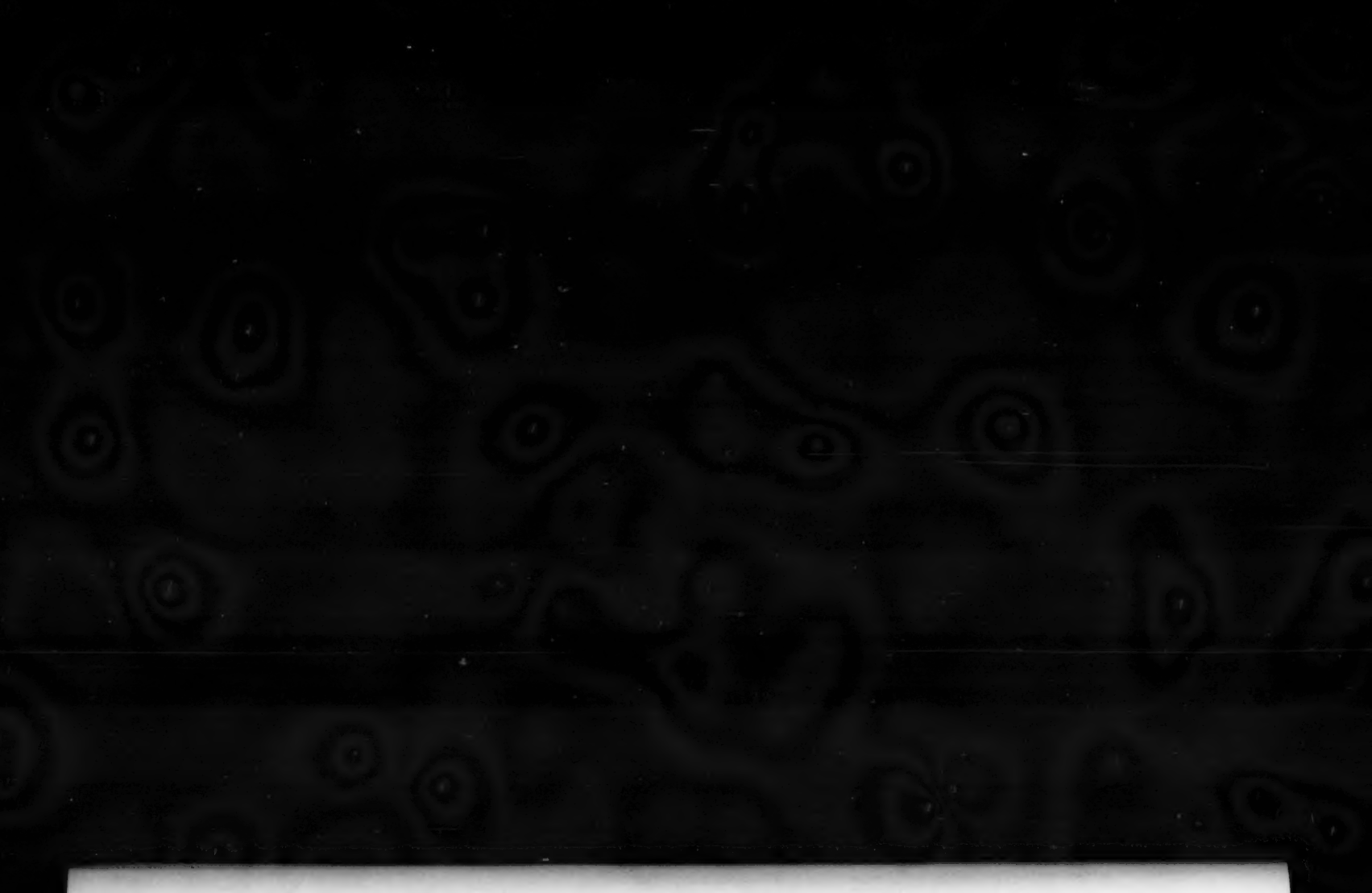
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